COMPUTER LANGUAGE™

VOLUME 4, NUMBER 11

NOVEMBER 1987

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PATTERN MATCHING: THEORY VS. PRACTICE

MULTIPLE WORD SEARCHES WITH LFIND

MEGASORT: THE ULTIMATE SORT?

A FORMULA FOR SYMMETRICAL DESIGN

SYNCHRONIZATION IN HARD-TO-EASY DESIGN

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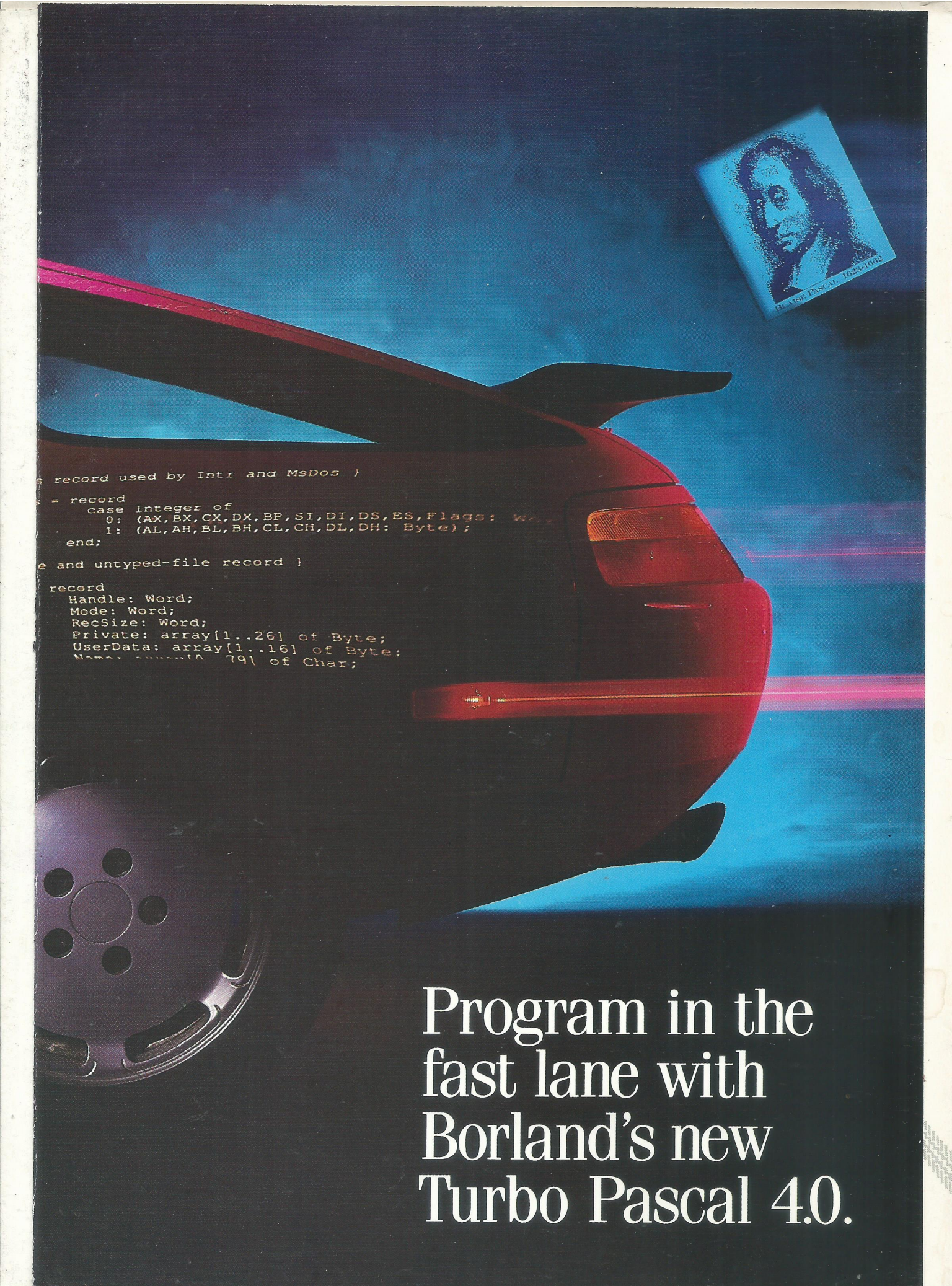
record used by Intr and MsDos }
= record
case Integer of
0: (AX,BX,CX,DX,BP,SI,DI,DS,ES,Flags:
1: (AL,AH,BL,BH,CL,CH,DL,DH: Byte);
end;
e and untyped-file record }
record
Handle: Word;
Mode: Word;
RecSize: Word;
Private: array[1..26] of Byte;
UserData: array[1..16] of Byte;
of Char;
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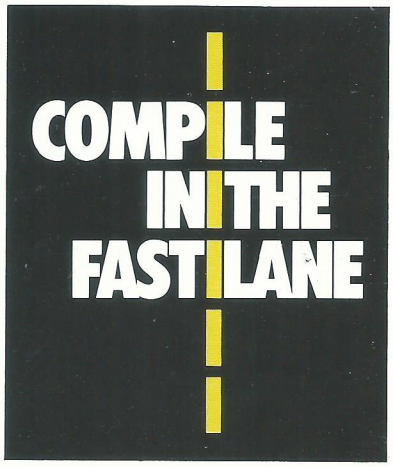

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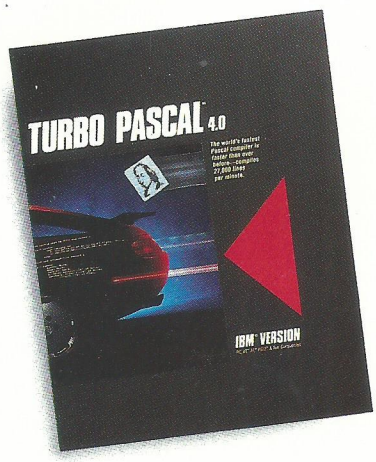

4.0 uses logical units for separate compilation

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4.0's cursor automatically lands on any trouble spot

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4.0 gives you an integrated programming environment

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You'll never lose your mind, because 4.0 never loses your place

Whenever you re-load 4.0, it remembers what you and it were doing before you left. It puts you right back in the editor with the same file and in the same place as you were working last.

*Run on an 8 MHz IBM AT.

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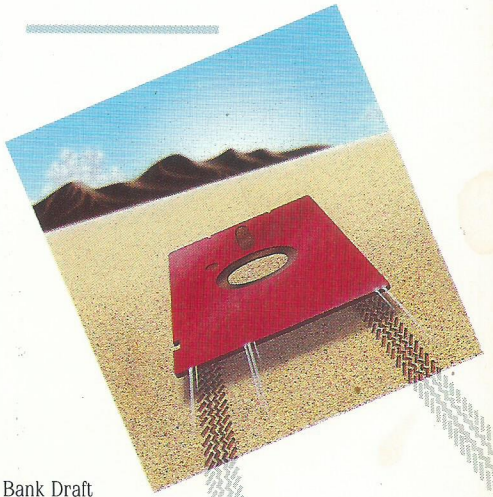

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Sieve of Eratosthenes, run on an 8MHz IBM AT

Since the source file above is too small to indicate a difference in compilation speed we compiled our GOMOKU program from Turbo Gameworks to give you a true sense of how much faster 4.0 really is!

Compilation of GO.PAS (1006 lines)

	Turbo Pascal 4.0	***Turbo Pascal 3.0***
Compilation speed	2.2 seconds	3.6 seconds
Lines per minute	27,436	16,750

GO.PAS compiled on an 8 MHz IBM AT

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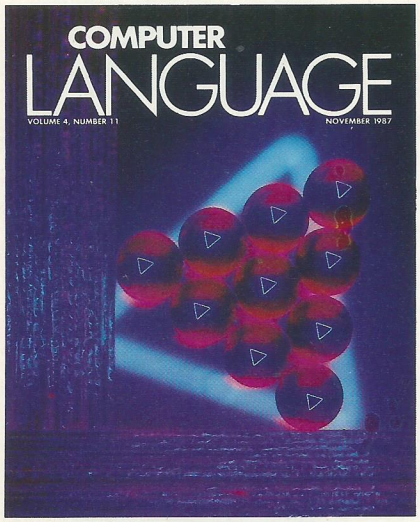

ARTICLES

Pattern Matching Alternatives: Theory vs. Practice ____ **34**
by Jack Purdum
This article complements last year's Boyer-Moore string searching article, comparing the Boyer-Moore algorithm with Knuth-Morris-Pratt and brute force approaches to large character sequence searches. Purdum points out that theoretical testing of an algorithm's speed isn't always a fair judge of how it will perform in practice, and uses the results of 10 timing tests to illustrate his point.

Multiple Word Searches With LFIND ____ **47**
by E.J. Smith
LFIND offers many advantages over the DOS *FIND* command: it does multiple word searches, isn't case sensitive, displays the line in which a word is found, and shows the line number of the text file. One of LFIND's most attractive features, though, is that it takes the same amount of time to search for 50 words as for one word.

A Recipe for Self-Decorating Eggs ____ **55**
by Clifford A. Pickover
The simple formula presented in this article uses real numbers instead of imaginary ones to create an infinite number of "chaos eggs"—egg-shaped tiling patterns that bear a striking resemblance to the artwork of some ancient cultures.

Megasort: A Distribution Sort ____ **63**
by Steve Heller
Using Turbo Pascal and something called "distribution counting" (described in volume 3 of *The Art of Computer Programming*), the author created a short, fast distribution sort known as Megasort. One of Megasort's biggest advantages is that its execution time is linear in the number of items to be sorted.

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Editor's Notes

"The study of algorithms is the study of the very heart of computing," wrote Jon Bentley in "An Introduction to Algorithm Design" (*IEEE*, Feb. 1979, pp. 66-78). Algorithms have always been the focal point of *COMPUTER LANGUAGE* editorial; this issue is our third annual issue on the subject.

Donald Knuth's basic definition of an algorithm is "a finite set of rules which gives a sequence of operations for solving a specific type of problem" (*The Art of Computer Programming*, vol. 2, "Fundamental Algorithms," Addison-Wesley). To that definition he adds five important features:

"Finiteness. An algorithm must always terminate after a finite number of steps.

Definiteness. Each step of an algorithm must be precisely defined.

Input. An algorithm has zero or more inputs, that is, quantities that are given to it initially before the algorithm begins.

Output. An algorithm has one or more outputs, that is, quantities which have a specified relation to the inputs.

Effectiveness. An algorithm is also generally expected to be effective...all of the operations to be performed...must be sufficiently basic that they can in principle be done exactly and in a finite length of time by a man using a pencil and paper."

The bottom line, notes Knuth, is that a programmer wants good algorithms in a loosely defined aesthetic sense, judged by such criteria as length of time to execute, adaptability, and simplicity and elegance.

Knuth's insights from *The Art of Computer Programming* are given here to provide a bit of a framework for examining and trying out the algorithms presented in this issue.

"Pattern-Matching Alternatives: Theory vs. Practice," written by Jack Purdum, picks up from where last year's "Searching for Strings with Boyer-Moore" left off. Purdum compares Boyer-Moore, Knuth-Morris-Pratt, and brute force approaches for searching a large sequence of characters for a match on a specific character pattern and comes up with some very interesting conclusions.

LFIND, a list-find program similar to the DOS *FIND* command, is described by E.J. Smith in "Multiple Word Searches with LFIND." LFIND is a fast, multiword search program that accepts a list of words and searches for them in a single pass.

Of course, we couldn't have an algorithms issue without a sorting article. Steve Heller presents Megasort, a distribution sort he claims is no more than a constant factor slower than any other sort and faster than almost any other on large arrays.

Finally, we just had to give you an unusual and slightly off-beat algorithm—one for generating intricate tiling patterns. The algorithm, developed by Clifford Pickover, yields egg-like shapes called "chaos eggs." These chaos eggs exhibit striking similarity to some of the patterns seen in the artwork of ancient cultures.

The best thing to do with these algorithms is jump right in and play around with them. Check their effectiveness. As Knuth says, "An algorithm must be seen to be believed, and the best way to learn what an algorithm is all about is to try it." Have some fun!

Regina Starr Ridley

Regina Starr Ridley
Editor

COMPUTER LANGUAGE code can be obtained from CompuServe (type "GO CLM" at the prompt and you'll be in our SIG), USENET ("mod.sources"), and Bulletin Board Services in the U.S. and Canada. Bulletin board parameters are 8 data bits, no parity, 1 stop bit, full duplex, and 300 or 1200 baud.

Complete codes listings for all issues since the Premier in 1984 are available from the Chicago BBS and CompuServe. Code on the other BBSs goes back six to 12 months.

COMPUTER LANGUAGE code is also available on disk from the IBM PC User Group in Austria. For further information contact them at Hasibederstr. 2/64/6, B.O. Box 40, A-1225, Vienna, Austria. Telex: 1-11010 tzxt, attention: IBM PC User Group.

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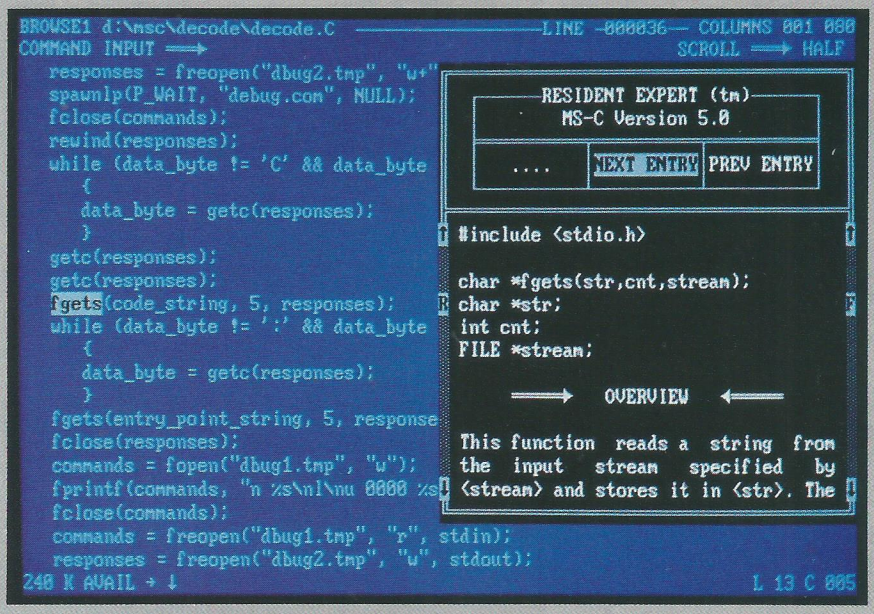

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CIRCLE 4 ON READER SERVICE CARD

FEEDBACK

Artwork: Steve Campbell

Variation on a scheme

Dear Editor:

In "From Turbo Pascal to Assembly and Back" (*COMPUTER LANGUAGE*, Sept. 1987, pp. 51-56), Michael Bertrand used a rather roundabout method of accessing PC registers from within Turbo Pascal. I would like to present a much simpler and clearer method of doing this.

The Turbo Pascal 3.0 manual documents the MS-DOS procedure on page 208. It shows an alternate definition of the PC registers for use in the MS-DOS and *Intr* parameter (Listing 1).

This approach allows you to access whole registers, or just the high or low bytes, without any extra programming. The get-time procedure can be rewritten to reflect this simplification (Listing 2). This approach makes the code easier to understand because it is more similar to the assembly language itself.

It also eliminates the confusion involved when loading AL with zero in order to get the interrupt parameter into AH (in this particlar case, interrupt 21H doesn't check AL for anything, anyway). Also, the *Hi* and *Lo* functions are now unnecessary because the high and low bytes of the registers are accessed directly.

In other programs, this approach eliminates the need to multiply by 256 and the use of *Shl* (shift left) to manipulate registers.

Mike Barnard
Fayetteville, N.C.

Michael Bertrand responds: I'm aware of this variation but didn't include it because variant records can be confusing.

Library closed

Dear Editor:

In their interesting article on Turbo Pascal ("7 Turbo Pascal Idiosyncracies and How to Deal With Them," *COMPUTER LANGUAGE*, Sept. 1987, pp. 59-64), Tom Rugg and Phil Feldman suggested exploring the machine code generated by Turbo Pascal. This task can be made easier by compiling your program as a .CHN file instead of a .COM file. This approach will cause Turbo Pascal to omit the 11K of run-time library, thus producing a smaller file that contains only your program code.

Colin J. Davies
Granada Hills, Calif.

Tom Rugg and Phil Feldman respond: Good suggestion. This approach works well if you have no need to look at that 11K of code generated for Turbo Pascal's internal subroutines. In our experience, however, most programs make frequent calls to these subroutines, and it is often necessary to figure out what they do.

In defense of code

Dear Editor:

As a systems programming manager on a mainframe system for over 10 years, I would add the following comments concerning source code in response to Vince Taylor's letter (Feedback, *COMPUTER LANGUAGE*, Sept. 1987, p. 9).

- In a production shop, the availability of source code for any major software package is almost mandatory.
- When a software bug is encountered at three in the morning or on a weekend, one cannot usually wait until normal working hours to diagnose the problem. The availability of source code can enable an experienced systems support staff to diagnose and, in many cases, solve a serious bug.

```
TYPE RegisterList = RECORD CASE INTEGER OF
1: (AX,BX,CX,DX,BP,DI,SI,DS,ES,Flags: INTEGER
2: (AL,AH,BL,HB,CL,CH,DL,DH: BYTE);
END;

VAR Registers: RegisterList;
```

Listing 1.

```
PROCEDURE Get_Time (VAR Hour, Minute, Second, Hundredth: BYTE);

Type RegisterList + RECORD CASE INTEGER OF
1: (AX,BX CX,DX,BP,DI,SI,DS,ES,Flags:INTEGER);
2: (AL,AH,BL,BH,CL,CH,DL,DH: BYTE);
END;

VAR Registers: RegisterList;

BEGIN
   WITH Registers DO
      BEGIN
         AH := $2C;     { Get the time from DOS }
         MsDos(Registers);  { Make the DOS call (Interrupt 21H) }
         Hour :=CH;
         Minute := CL;
         Second := DH;
         Hundredth := DL;
      END;    {  with  }
 END;  { procedure Get_Time }
```

Listing 2.

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You've seen the ads: Datalight challenges Microsoft. Our C compiler expert Richard Relph saw the ads and sent for Datalight's compiler. What he found when he began to test it must have given him mixed feelings. For the past two years Richard has been involved in developing the DDJ suite of benchmarks for C compilers. The Datalight compiler flattened those benchmarks, making them worthless.

With the apparent glut of C complier suppliers vying for the MS-DOS market, it was only a matter of time before one of them decided to step above the crowd and provide a reliable optimizing C compiler. Datalight beat all others to the punch by delivering such a compiler February of this year. (Dr. Dobbs Journal, August 1987)

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CIRCLE 5 ON READER SERVICE CARD

■ Source code availability enables inserting a vendor's patch with a minimum amount of trouble. Unless a vendor is able or willing to guarantee that updated versions of the product will be made available whenever problems are encountered, source-level patching is the only way to install extensive bug fixes.

■ Most large MIS/DP shops will have unique requirements or workloads that require either functional changes to the software or the tweaking of the software to enhance performance. Most of us understand well the pitfalls of local code and recognize that vendors are under no obligation to fix modified versions of their products. The availability of source code, however, enables us to make these modifications.

I applaud Taylor for making source code available, and wish more vendors did likewise. I have no problem with paying a reasonble fee for either source code or the licence to a vendor's source code. Most of my points are relevant to large MIS/DP shops, but as more vendors try to sell to our market, concerns of this nature are going to have to be addressed.

Richard H. Miller
Head Systems Support
Baylor Computer Center
Houston, Texas

Anarchy (honestly) now!

Dear Editor:

I really enjoyed P.J. Plauger's "Honestly, now," (Programming on Purpose, *COMPUTER LANGUAGE*, Sept. 1987, pp. 13-19). I feel many valid points were made. As a bit of an anarchist myself, however, I feel Plauger sorely misrepresents the political philosophy of anarchy.

Some anarchists, at times, have damaged property, hurt people, and bored others at parties while attempting to install their political philosophies. *No* political philosophies are, to my knowledge, devoid of a few proponents who have tried these techniques. According to *Oxford American Dictionary*, an anarchist is "a person who believes that government and laws are undesirable and should be abolished." From my estimation of some of the affairs in which Plauger was involved, government and laws were far from desirable. The anarchists with whom I have chosen to associate have a high regard for people and the objects they use. ("Property" can imply a legislated status to objects.) Most importantly, some anarchists are a *blast* at parties.

Dale Strickler
McVeytown, Pa.

P.J. Plauger responds: I wasn't referring to the philosophy of anarchy, which aspires to an attractive but unattainable ideal, but to the practice of self-styled anarchists who suffer from the delusion that disrupting society will somehow awaken the populace to an instant appreciation of the anarchist's distress.

Heap o' code

Dear Editor:

First, please allow me something that is more than simply a formality. Your columnist, P.J. Plauger's two texts, his column, and his participation in the X3J11 process I consider to be major contributions to my career, and to our profession. You deserve thanks from all of us!

Not being above the "careful study and imitation of good programs," I was delighted to see a discussion of heap sort in Plauger's "Programming on Purpose," (*COMPUTER LANGUAGE*, Oct. 1987, pp. 17-22). It has served us well! I was reminded of some code in our merge sort: the procedure is named *Reheap* (in keeping with your text's original naming

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CIRCLE 7 ON READER SERVICE CARD

scheme). However, the comment on *our* procedure reads "Actually, just puts the smallest one first." I'm not sure I should be bragging about the discrepancy between our procedure's name and operation, though. However, I do want to point out to you that (as far as I can equivicatingly tell) there is no need to do a heap sort, however elegant it may be. As our code's comment described, the routine need only return the *heap* with the first element being its smallest. This, of course, makes for smaller, faster, and less buggy code, eh?

Tom Field
Quickpen International
Englewood, Col.

Adding to the repertoire

Dear Editor:

Thank you for your review of PMI's Repertoire (Software Reviews, *COMPUTER LANGUAGE*, Sept. 1987, pp. 118-119). An additional point and a minor correction ought to be made, however.

A month or two after Warren Keuffel finished his review, Logitech began shipping a remarkable new linker with Modula-2/86 v. 3.0. Unlike most other DOS linkers, it is capable of linking in only as much code as a program actually references, regardless of the extent to which the library is granularized into separate modules. As a result, Repertoire's enormous size and tight integration no longer cause needless code to be linked in; an application incorporates only as much code from a library as it really executes.

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We realize that this feature is not well documented in the present release. Keuffel correctly described the primary purpose of Repertoire's indexed file system as the storage of complex variable-length and list oriented data.

Cole Brecheen
Vice president, PMI

A paradoxical exclusion

Dear Editor:

It was interesting to read Richard Finkelstein's "Wrap-up rebuttal" (Feedback,

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CIRCLE 9 ON READER SERVICE CARD

COMPUTER LANGUAGE, July 1987, p. 11). Even though I am not an employee of ANSA Software or heavy user of Paradox I found his justification for its exclusion from his review to be non-informed.

For example, he gives as one of his reasons the fact that the reviewers chose to review only nonprocedural, set-oriented products. But in the original review (Software Reviews, *COMPUTER LANGUAGE*, May 1987, pp. 89-116), one of the products reviewed was PROGRESS which, it was stated, has no nonprocedural way to build screen entry forms. He then gave an example of highly procedural PROGRESS code to show how table updates might be done. In PARADOX, the applications generator allows completely nonprocedural specification of an entire application, screens included. You would never need to write such code.

In addition, I find it odd for him to say that a package with SQL has anything going for it over the QBE used by Paradox, because the underlying techniques and logic required to execute a QBE query are identical to those needed to execute SQL, with the exception of the nested SQL query blocks.

QBE queries are as powerful as any equivalent to the active set of records returned by an SQL query. And PAL, the applications language for Paradox is at least as nonprocedural as any other programming langage with embedded SQL, with the exception of something like Informix/4GL. But with Paradox, the Apgen is so powerful, you may never need to write any code of any generation, which is about as nonprocedural as most of us could hope for.

Gary T. Lang
Ratliff Software Productions Inc.
Diamond Bar, Calif.

Richard Finkelstein responds: As I mentioned in my review, PROGRESS has some procedurality. Better examples of nonprocedural SQL development systems include XDB, Oracle, Ingres, and Informix, the highest rated products in the annual data base derby competition, which measures nonprocedurality. Unfortunately Paradox declined to enter the derby last year. Paradox as a PAL language appears to be very similar to BASIC, with the exception that PAL allows for QBE statements. QBE is a subset of SQL and cannot perform many equivalent SQL functions, including relational division operations. Hundreds of application generators for procedural languages are available, many of them equal to or surpassing Paradox. Since developers have to enhance, maintain, and debug the object code of these generators, it is important that the object code be nonprocedural. PAL is not.

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PROGRAMMING ON PURPOSE

Synchronization in hard-to-easy design

By P.J. Plauger

Method.
Hard-to-easy design.

Description.
Hard-to-easy design focuses on safe cooperation among sequential processes. When independent agents endeavor to share data, synchronization is required to prevent race conditions and data corruption. When synchronization is poorly implemented, lapses and deadlock may occur.

The name derives from the observation that synchronization is hard to get right and best dealt with early on in the design process. The primitives used to effect synchronization vary widely among different systems. Safe operation often can be achieved only at the cost of overall system performance. Thus, synchronization requirements should be kept to a bare minimum.

Documentation.
Timing diagrams show critical transitions that assure proper synchronization.

Limitations.
You cannot always separate synchronization issues from background computation, particularly in real-time systems with sophisticated feedback. It is hard to avoid all possibility of deadlock in a complex system.

Once upon a time, computers were fairly simple. When your program wanted to read a card, it issued a *READ* instruction to the card reader, then proceeded to twiddle its thumbs. Nothing else happened while the picker separated the bottom card from the deck in the input hopper, the feed mechanism dragged the card past the read heads, and the stacker dropped it neatly in the output hopper.

A very large fraction of a second after your program issued the *READ* instruction, it moved on to the next instruction, secure in the knowledge that the data from the card was copied into the designated buffer in memory. Even in those unhurried times programmers lamented the milliseconds wasted while bits of matter were coaxed into motion by various peripheral devices.

So computer designers developed the input/output channel, a moderately stupid processor that knew just enough to supervise the transfer of data to or from a peripheral device. The central processing unit issued its *READ* request to the I/O channel, then went on about its business. When a transfer was complete, the I/O channel jerked the chain of the CPU by sending an interrupt. Your program could then note, in some fashion, that the transfer was complete, and liberate the buffer in memory for other uses.

At that point the systems programmers made a mistake. They assumed that the control of overlapped I/O should be put into the hands of every applications programmer. Suddenly, FORTRAN programmers had to deal with new I/O options of frightening power. We had to specify event flags to be set on successful completion of a transfer. We had to specify handlers to be entered on transfer error, end of file, and possibly even successful completion. Most importantly, we had to learn to keep our cotton-picking hands off the I/O buffer until each transfer was complete.

Synchronization is hard to get right and best dealt with early on in the design process

If we didn't take on all this baggage, we suffered the stigma of using the computer inefficiently (a social faux pas roughly equivalent to turning down a date with Brooke Shields). If we did take it on, we were forced through a programmed learning course in how to nominally synchronize cooperating sequential processes—with no textbook for the course and our application program providing the only courseware.

Eventually, the systems programmers took pity on FORTRAN programmers. They provided spoolers that used overlapped I/O to read ahead on card readers and write behind on printers and punches. We went back to writing programs that completed each transfer before proceeding, certain that most transfers involved simply a memory-to-memory buffer copy. Computer utilization was up and we were in a state of social grace. Only the macho types persisted in coding their own overlapped I/O.

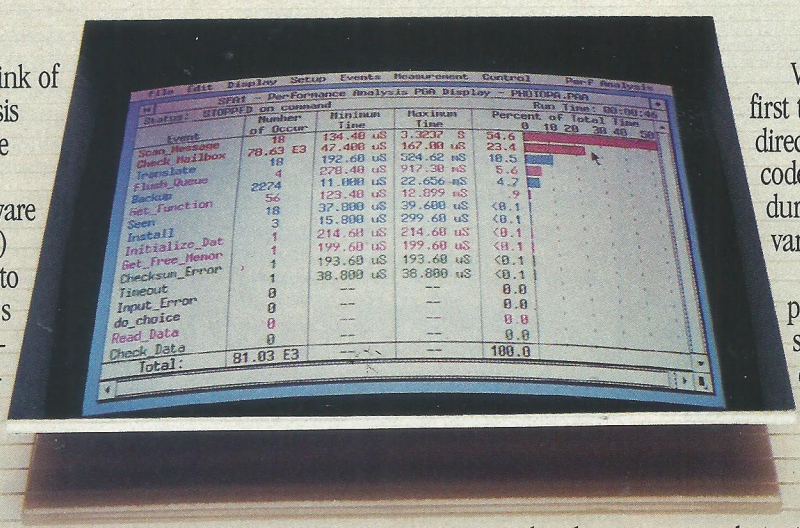
Just as that flap was settling down, another one emerged. Computers were being equipped with multiple terminals, allowing several people to simultaneously negotiate with separate programs, all running on the same machine. Conversational time-sharing was invented as a way of keeping people seated while waiting for better response time instead of milling about the ready room waiting for spooled printer output.

To make all this happen, systems programmers developed operating systems that could juggle multiple processes or separate threads of control. (Think of a process as a program that thinks it has a whole machine to itself, even though it is a virtual machine that is just a subset of the underlying hardware.)

At that point the systems programmers made another mistake. They assumed that the ability to run multiple processes should be put into the hands of every applications programmer. Suddenly, PL/I programmers had to deal with tasking options of frightening power. We had to specify event flags to be set on successful completion of a subtask. We had to specify handlers to be entered on tasking errors. Most importantly, we had to learn to keep our cotton-picking hands off any storage used by another task until its usage was assuredly complete.

Not using tasking never quite attained the stigma associated with not using overlapped I/O. What was worse, overlapped I/O looked easy to use. Nowhere in the PL/I manual was the least hint that tasks were hard to specify safely, expensive to start up, or next to impossible

Everything you know about performance analysis is wrong.



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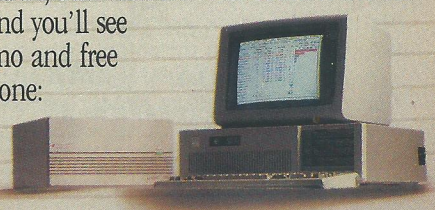

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to debug. Once again, the tuition we paid did not entitle us to a textbook.

Eventually, the systems programmers again took pity on us. They provided command interpreters that start and administer multiple processes on our behalf. They gave us processes that run on separate virtual machines and communicate only through the operating system.

They invented pipelines and first-in-first-out (FIFO) files for sequential data passing. They invented record locking for shared access to files. By eliminating most of our freedoms, they set us free. Only the macho types persisted in writing unstructured, multithread programs.

I have just described what is generally regarded as the first three generations of computers. (The distinction between generations has since dissolved in an acid sea of marketing hype.) In summary, these are:

- First generation—a single thread of control in a private memory
- Second generation—overlapped I/O, used to improve the performance of a single thread of control in a private memory
- Third generation—multiprocessing used to support largely independent processes, each a single thread of control in a private memory.

The point I am belaboring is that using overlapping multiple operations to work toward a common goal is a great way to improve the performance of a computer system but is very hard to control. Synchronizing logic is the hardest code in the world to design, debug, and tune. Once you get it right, you stuff it in a black box, hold it at arm's length, and treat it as just another peripheral connected to your first generation virtual machine.

Ninety-odd percent of the code you write should be written for a single-thread environment. Otherwise, you'll pay a stiff premium on everything you write. This is why I call writing synchronizing code hard-to-easy design. If you have to do it, do it first, before the problem gets cluttered with more mundane details. Identify where cooperating sequential processes absolutely must share information to cooperate and keep that interface to a bare minimum. Then encapsulate that interface, both data and synchronizing functions, and clearly document the rules for using it. Finally, debug the synchronization code alone as best you can before you go on.

This fear of synchronization code may appear unseemly. All I can say is that of all the designing and debugging I have ever done, none has come close to presenting the same level of difficulty.

With a complex program you develop a feel for how many changes you can make before losing control of the program. I have found that an operating system kernel that is the same size as a language translator can safely tolerate only about a fifth as many changes as the translator before it breaks. And when an operating system breaks, it quickly turns into an uncooperative lump that is inert at best and insanely malicious at worst.

If you are now sufficiently frightened, let's look at what it takes to synchronize multiple activities. Once again, I will recapitulate (more or less) the evolution of multithread systems from the simplest to the most ambitious.

Say you need to design a microprocessor-based system that gathers data from a number of sources. The easiest way is to provide a simple hardware interface for each of these sources that holds onto the most recent data until the computer can do something with it.

From time to time, your program examines a status bit in the control registers for each of the hardware interfaces. If the bit is set, your program knows that data is present. It reads the data and clears the control bit to inform the hardware interface that the data has been delivered. This matters only if your program fails to collect a piece of data before the next one comes along.

At that point the hardware interface suffers a data overrun, which it should report to your program via yet another status bit. Your program is obliged to do something sensible in the presence of data overruns. The following is an example of the control code:

```
FOREVER
   IF (<data overrun>)
      <evince concern>
      <clear overrun>
   IF (<data ready>)
      item := <input data>
      <clear data ready>
      process(item)
```

This method is popular for interfacing to computers, particularly microprocessor-based systems, where cost and complexity must be minimal. It requires a style of programming called polling. The design centers around an infinite loop that polls each device in turn, looking for more work to do.

Synchronization is simple because the control program gathers data only when it is ready for it, then completely disposes of the data before assuming the next task. Provided that system performance is high enough to keep data overruns to a minimum and that such data overruns are not cataclysmic, the solution has ad-

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mirable simplicity. Notice how much it resembles a first generation computer performing nonoverlapped reads and writes.

Polling breaks down, however, when data from one or more sources occurs in bursts. There may be enough system capacity to handle all data presented in any given five-second interval, say, but a single device may sometimes need attention 50 times per second to avoid data overruns.

You can extend the capacity of polling systems to handle such cases in two general ways. You can build hardware that queues up data from sources that occur in bursts to tide the interface over until the control program can service it. Or you can rewrite the control program as two or more control loops, servicing devices that occur in bursts in a fast loop and performing longer computations in a slower loop.

The first approach raises hardware costs and the second raises software complexity. However, both can help you delay taking on even more hardware costs and software complexity.

A more robust solution to the problem of data that occurs in bursts is to let its hardware interface generate an interrupt whenever it needs attention. When an interrupt occurs, the computer saves whatever information is needed to restore the state of the current activity, then transfers control to a piece of software called an interrupt handler.

A properly designed handler services the attention request from the hardware interface to the point where the interface no longer feels motivated to generate an interrupt, then terminates by restoring the state of the current activity. Whatever process was running is oblivious to its interruption.

What an interrupt does, in effect, is move the synchronization point for a device further inboard from its hardware interface. You can bring the full power of the CPU to bear on buffering data to be transferred and reduce the need for special-purpose hardware in the interface. What an interrupt costs you is an added demand on the processing power of the CPU and added software complexity in dealing with the necessary synchronization.

Let's say you are using an interrupt handler to buffer data into the array *in_data*, of size *N*. You can maintain a circular buffer with an index and a count:

```
IF (N <= in_count)
   <data overrun>
ELSE
   i := in_next + in_count
   IF (N <= i)
      i := i - N
   in_data[i] := <input>
   in_count := in_count + 1
```

To process this data, you need a background loop something like:

```
FOREVER
   WHILE (in_count = 0)
      <wait>
   item := in_data[in_next]
   in_next := in_next + 1
   IF (N <= in_next)
      in_next := 0
   in_count := in_count - 1
   <process item>
```

For output devices, you write very similar code. The difference is that the background loop must *<wait>* when the output buffer is full, and the interrupt occurs when more data can be output. (Restarting an idle output device is slightly more complex, and I will gloss over the differences for now.)

But the loop just shown has a problem. Whenever an interrupt is serviced, the handler assumes that certain relationships occur among the control variables for the buffer:

- There are *in_count* items unconsumed in the buffer.
- *In_count* may be zero, but it never exceeds *N*.
- The next item to process, if present, is at *in_data[in_next]*.
- *In_next* may be zero, but it never equals or exceeds *N*.

Since interrupts may generally occur between any consecutive instructions (or even in the middle of a particularly complex instruction on some machines), the interrupt handler may be entered at any point in the background loop that is processing the input data. The handler may even be entered partway through one of the statements since high-level language statements frequently translate to several machine instructions.

You can identify any number of places where the necessary relationships do not hold among the control variables. Mucking with them at these places leads to much mayhem. The relationships hold at the beginning of the loop body. By the time execution gets to the end of the loop body, the relationships are restored.

The problem occurs in between, where the operations needed to update the state of the buffer are not atomic. Hence, this sequence of code is called a critical region. In a critical region, shared data is in an inconsistent state. Because the data is shared by agents that are proceeding

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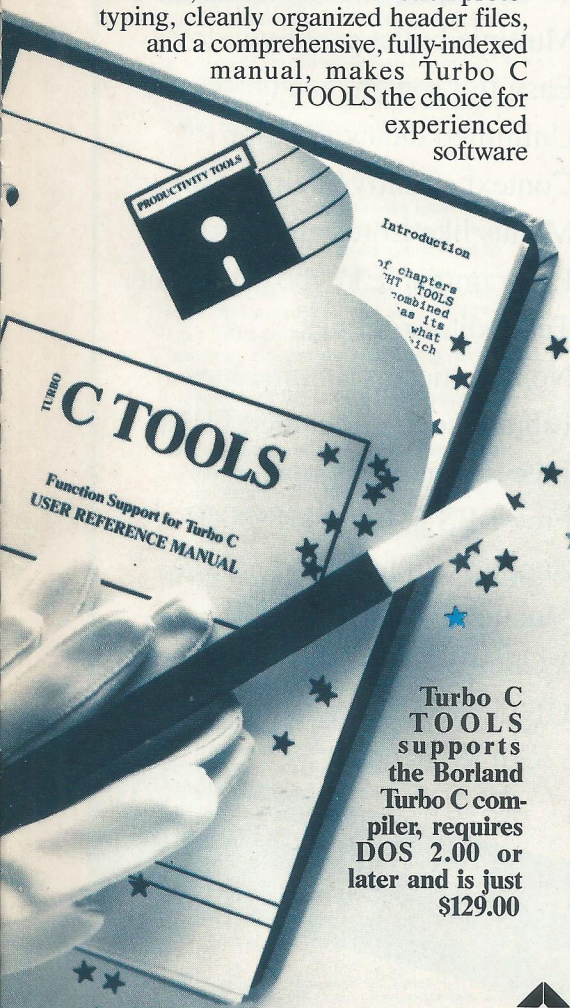

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asynchronously, it is never safe for more than one of the agents to be in a critical region for a given collection of data at the same time.

The interrupt handler contains a similar region of code, but it will always be executed atomically (unless there is a higher-priority interrupt that mucks with the same variables and can preempt execution). What you must do with a critical region is find a way to make it atomic.

Two fundamental approaches to making a critical region atomic are ensuring that no other concerned agents can execute while your program is executing a critical region and adding control variables that can be updated atomically to inform other agents when the critical region is busy. These agents must then elect to stay out of the critical region while it is busy.

Here, the other agent is the interrupt handler. In this case, you must dismiss the second approach because an interrupt handler has very little latitude. It must dispose of its latest input and return control, with a minimum of fuss, for two reasons:

1. The more an interrupt handler fusses around, the more likely it will cause a data overrun while it is preoccupied.

2. Any constructive fussing it might do will just involve additional synchronization problems somewhere else.

To keep interrupt handlers from interrupting critical regions, you must keep them from executing. Computers can generally disable or inhibit interrupts until a more opportune time, when the interrupts are enabled or permitted. The need to interrupt is not forgotten, its servicing is merely postponed. The background loop must be rewritten as:

```
FOREVER
   WHILE (in_count = 0)
      <wait>
   <disable interrupt>
   item := indata[in_next]
   in_next := in_next + 1
   IF (N <= in_next)
      in_next := 0
   in_count := in_count - 1
   <enable interrupt>
   <process item>
```

This code still assumes that *in_count* can be compared to zero with an operation that is either atomic or fail-safe. If you doubt this assumption, you must make the protected region even larger. Naturally, it is important to keep the amount of time interrupts are disabled and handlers are active to a minimum. Poor design or coding here can increase data overruns dramatically.

You should notice once more how much this program resembles a first generation computer performing nonoverlapped reads and writes. Most of the loop body in the previous example is just our old friend, the *READ* statement, in a new disguise.

Those of you who know something about the technology of synchronization may have noticed something odd. I have made it through most of a column without discussing gates, semaphores, queues, monitors, or any of the other higher-level concepts that fill many books and papers about synchronization. My reasons for this are:

- I wanted to pound home the historical lesson that first generation computing, isolated from synchronization issues, is the safest model for most program logic.
- I wanted to illustrate the nuts-and-bolts issues even the simplest computer interface must address.
- Most of the literature on synchronization deals with cooperating sequential processes that have more or less identical stature, whereas interrupts and background loops are intrinsically asymmetric.

There is lots more to talk about on this thorny topic. For instance, what happens when you have multiple interrupts to contend with? The best code for handling these cases is not always a simple generalization of the single interrupt case illustrated here.

Nor are your worries over once you have protected all your critical regions and made all your shared data accesses atomic. That just gets you in the game. Then you have to make sure the sequences of synchronized operations you specify make sense and never lead to deadlock.

We will consider these and other issues in the next column.

P.J. Plauger has coauthored several popular textbooks with Brian Kernighan, including The Elements of Programming Style *and* Software Tools in Pascal. *He is secretary of X3J11, the ANSI C standard committee, and convenor of the ISO C standard committee. He is also the president of Whitesmiths, Ltd.*

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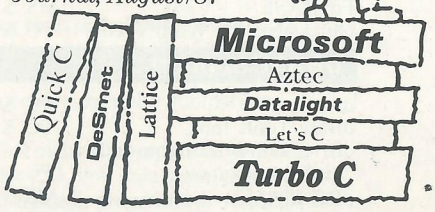

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DESIGNING WITH DATA BASES

Screen and report generators

By Matthew Rapaport

In the last issue, I began to cover a variety of tools associated with DBMSs called nonprocedural languages. I focused on list processors such as the *LIST* commands in Cosmos's Revelation and Dunn and Bradstreet Corp.'s NOMAD2, and I discussed the output capabilities of IBM Corp.'s Standard Query Language (SQL). I noted that SQL is capable not only of output from the data base, but input and update operations on the data as well.

The SQLs of Informix Software Corp.'s Informix and Unify Corp.'s UNIFY have this capability. In addition, Informix's SQL is capable of creating new data structures or modifying old ones, which makes it the only query language that meets all of E.F. Codd's specifications for the functional capability of a relational DBMS's nonprocedural interface.

The trade-offs for the flexibility of a full-featured SQL (as compared to a pure list processor) are a relatively complex syntax and the inability to create complex output formats (like checks replete with names, amounts, stubs, etc.) and perform complex input and update transactions involving data manipulation on a record-by-record basis. Another weakness of input with SQLs is that the operator is required to know precisely the order of fields in the external view or base relation. Input to a relation using SQL takes the following form:

```
INSERT EMPLOYEE JONES, JOHN,
    05/01/86, SENIOR MANAGER,
    48000.00, 10/
```

This input creates a new record in the relation *EMPLOYEE* with fields *LAST_NAME, FIRST_NAME, HIRE_DATE, TITLE, SALARY,* and *DEPARTMENT,* respectively. If the operator had inadvertently reversed the *TITLE* and *SALARY* fields, the insert would at best fail (if the DBMS was doing proper integrity checks) and at worst cause instant corruption of the data base.

Input in this manner is very useful during the development and testing of a new data structure and markedly enhances where preformatted data is fed to a batch SQL script. SQL is cumbersome and prone to error if used in on-line production applications.

This type of input may also be entirely untenable in large data bases (a typical production employee data base may have 200 or more fields describing each employee). For this reason, and because production applications frequently require reports with elaborate titles, footings, or other page formats, two other specialized nonprocedural languages and/or utilities have become standard accoutrements of most DBMSs: screen and report generators.

Of the these two tools, screen generators are generally easier to use. Screens can be formatted randomly. They require titles and appropriate prompts, but otherwise data fields can be displayed or input in any order along with defined fields and other variables.

In contrast, report generators must account for the fact that output generally includes headings, footings, subtotal breaks, or other special fields that should be properly placed on hard copy that usually moves in one direction only. Screens may have to test and format data in complex ways, but this happens behind the scenes, while the results of complex manipulations must be revealed, sometimes in complicated images on paper by report generators.

Thus, while screen generators must sometimes handle intricate inserts and updates of numerous relations, report generators must not only report from one or more base tables, but also be able to do elaborate page formatting in a less forgiving medium than the CRT.

In covering a range of screen generators, it seems appropriate to start with that of Ansa Corp.'s Paradox. In some ways the Paradox user interface is a lesson in clean screen generation. To begin with, you can insert or update values in a data base through operations on data displayed in tabular format, much like that of a spreadsheet. One or more tables can be displayed on the screen at the same time. Fields that will not fit in a column can be expanded with the touch of a key, filling the screen both horizontally and vertically for extensive text entry, then instantly collapsed for entry of other fields.

A single keystroke allows scrolling up or down through multiple tables, and all data entry is instantly checked against edit criterion established when the table structure was created. Unfortunately, so many end-user application specifications demand the more traditional, one-record-at-a-time form of data entry, update, and query. Using the Paradox table format quickly becomes natural and can be a tremendous time-saver since multiple records can be edited with commits to the data base executed over multiple changes, saving disk I/O.

With Paradox, it is possible to build the traditional end-user data entry interface. The paradox forms facility allows easy creation of data entry screens, including easy paging through multiple screens of highlighted boxes and calculated values (based on a predicate relation between one or more fields in the current record, constants, or dates).

One advantage to forms is the multiple display of fields on one screen, from one record at a time, compared to a tabular layout. Paradox forms can display data from one table at a time only. Calculated fields can be useful and cannot be displayed using the tabular representation. Calculated fields such as *DUE-DATE: ([INVOICE-DATE]+30* and *OVER-DUE-CHARGE:([INVOICE-TOTAL]*[CUSTOMER-INCREASE-RATE])+[INVOICE-TOTAL]* can be established for display purposes only. They are not stored in the data base.

However, screen forms can be printed and serve well as purchase orders, invoices, or even checks, with the limitation that calculations cannot be based on reading values from other tables (for example, you cannot calculate the net amount on a paycheck by reading a tax table and deriving tax amounts).

Input, update, and deletes are single-keystroke operations, with the effective keys consistently established in the Paradox interface. As usual, security and convenience are at odds with one another.

One of the problems with Paradox's easy access to data is that *DELETE* operations cannot be shut off unless one goes to the trouble of programming the screen directly via Paradox's PAL language. While PAL is a good language (and will be discussed in a future column), having to use it defeats the whole purpose of having such a powerful nonprocedural screen interface to begin with.

Paradox illustrates how a given product, through the interface philosophy its creators choose to implement, is best suited to one niche only, even though its underlying DBMS is capable of handling the data structures and manipulations of dissimilar environments. For example, Paradox is easily capable of handling the payroll requirements of a small- or medium-sized company, but the sensitivity and historical significance of the data prevents data-entry operators from using the facilities of the entire Paradox nonprocedural user interface.

In contrast, an application with a strong management information systems (MIS) leaning is ideally suited to the Paradox philosophy. Here data may be deleted and manipulated in easily created temporary tables for "what-if" analysis or data summary.

* Before turning to the screen facilities of the next DBMS on our list, it is worth noting briefly the facilities of Borland International's Reflex in connection with spreadsheetlike screen interfaces. Reflex is not a DBMS because it cannot operate on more than one table at a time; it possesses no facilities for intertable relational edits. Like Paradox, it can display a table for entry, update, or inquiry of data. Standard entry forms can be created with one or more pages.

In many ways Reflex resembles the Paradox interface, but it has more features for single-table manipulation. For example, it instantly cross-tabulates two different fields (such as salespeople and their sales figures by month), displaying one field along the *X* axis of a table and the other on the *Y* axis. Reflex also takes multiple fields from a single table and instantly graphs their relationship in one of several ways: bar, line, pie, etc.

In addition to this, Reflex has a spreadsheetlike capability to replicate data down rows, producing new data according to a formula. For example, a given table may have rows that represent months and columns that represent sales figures for different regions. These rows can be duplicated, in effect projecting the data into the future, with sales made to vary in relation to a user-created function. In short, Reflex would be an excellent example of a versatile DBMS front end if its various capacities could automatically access the files of another vendor's underlying (and running) DBMS.

Given the ability of most DBMS systems to dump subsets of tables to ASCII files, Reflex can be used in conjunction with other systems to produce very sophisticated analytical systems. (Reflex can read ASCII files into its file system as well as several other formats directly.)

Screen Generators in other DBMS products are typically more difficult to master, but most are more powerful since they can update several tables in the same screen (or multiscreen set). Microrim's R:base System V screen generator, called Forms Express, can update five tables in one screen set. Like Paradox, R:base screens are generated with built-in code for handling insert, update, and delete activities in a single-keystroke manner.

R:base screens can be divided into regions of tiers within regions, allowing the user to display data from different tables in a combination of custom form and tabular display in the same screen. Furthermore, R:base System V provides mechanisms for restricting operations in any given screen. For example, it can prevent record deletions or allow updates but no inserts, or vice versa. It also enables automatic updating of one relation: a function is performed over an operator entry in another relation. Operator entry of a customer amount-paid in a table called CUSTOMER-RECEIPTS can be converted to bonus points, which are used to update a totaling bucket in the table CUSTOMER-BONUS-TOTALS.

The UNIX versions of Informix's and UNIFY's screen generators are not as powerful as those I've discussed. I have not yet tried the DOS versions of these products. Both will produce multipaged screens. Informix's screen generator updates multiple relations in the same screen set, but not in one screen. It cannot automatically update one relation based on an entry made to another. UNIFY's screen operator cannot handle more than one table in a screen form.

Informix screens can be customized after they are produced by the screen generator. The generator's output is an editable listing in a documented nonprocedural language. One can modify this code to move fields around the screen or between screens and to generate calculated fields that, like their Paradox counterparts, are not stored in the data base. Listing 1 is an example of the output of Informix's screen generator after customization.

The Informix screen language is capable of assigning default values, masks, enumerated types or ranges, and insert, update, and delete limits imposed on a field-by-field level. It can also assign relational edits otherwise not available in the Informix data dictionary. UNIFY's generator does not produce editable code but can create more elegant forms than the straightforward output of Informix. UNIFY screens, however, have the same limited I/O capabilities as Paradox screens; therefore a lack of ability to enhance them is not an asset.

Even with Informix's enhancement potential, such work requires knowledge of a programming language (albeit a high-level nonprocedural one). The Informix screen language is a good example of a specialized nonprocedural system. In some ways, working with it is like using the @ SAY logic of Ashton Tate's dBASE line, except that the record retrieval and update logic is built into the process by the initial screen generation and automatically connected to the appropriate keys.

The logic-handling cursor movement among the fields of the screen is also similar to that of Ashton Tate's dBASE line. When a developer customizes the code generated by Informix, *get, update,* or *delete* statements are not present.

In contrast, R:base System V has no code to customize. Its nonprocedural interface is two-dimensional, expecting the user to paint a screen with elaborate sequences of keystrokes and answers to questions posed by the utility software. Expertly working such a piece of software is just as difficult as mastering the older string language products (like Informix). Enhancing a screen in R:base means exercising the features of a substantial and dedicated editing system fully capable of turning any screen in a system into any other screen and as complex as a small-scale word processor or good line editor.

The screen generators of d:BASE III Plus and Revelation produce procedural code that can then be enhanced. Initially, these systems produce screens with simple functions, but a developer who knows how to subsequently handle their procedural languages can manipulate them. Revelation screens operate in interpreted or compiled mode.

In compiled operation, the screen runs from its generated procedural code, which is compiled to the Revelation runtime system (the compiler does not produce .EXE or .COM files). In interpreted mode, Revelation screens are similar to the screens of R:base, Paradox, and UNIFY. Achieving R:base-like performance with Revelation requires somewhat more work and learning. While the

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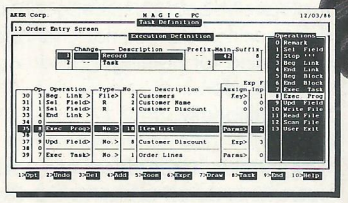

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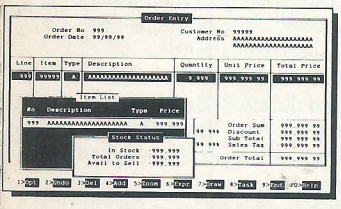

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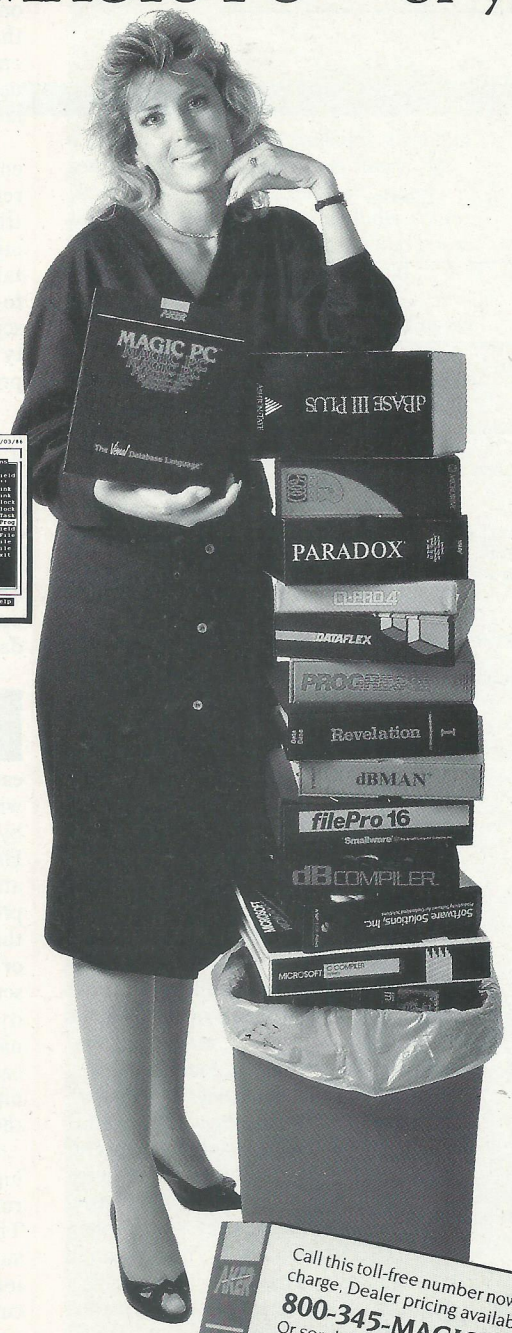

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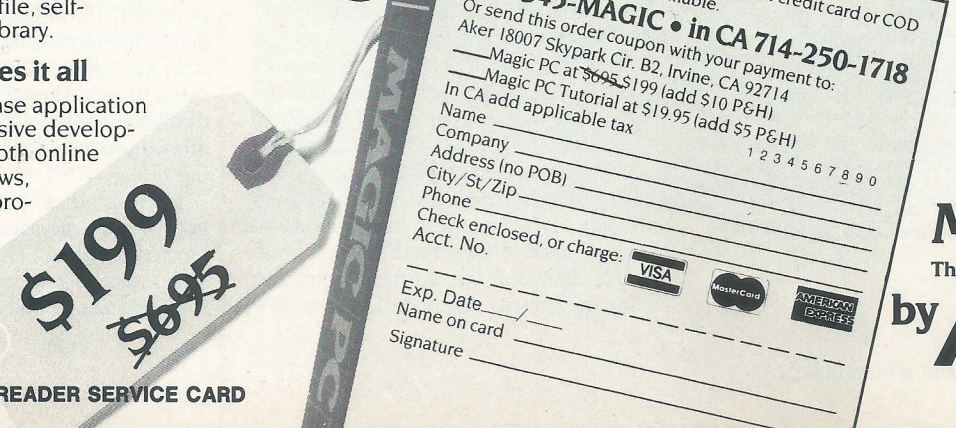

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CIRCLE 21 ON READER SERVICE CARD

```
Output of the Informix screen generator. The characters "o," "i,"
and "s" in the brackets represent the first characters of the
table names "orders," "items," and "stock." Their meaning is
derived from assignment statements following the screen layout.
Note the absence of an explicit loop, which compares to the high-
level procedural code generated by DataFlex in Listing 2.

data base stores

screen
{
--------------------------------------------------------------------------------
CUSTOMER INFORMATION

Number:     [c1          ]
Company:    [c4                    ]
First Name: [c2           ] Last Name: [c3             ]

Address:    [c5                     ]
            [c6                     ]
City:       [c7                ] State: [  ] Zipcode: [         ]
Telephone:  [               ]

--------------------------------------------------------------------------------
}
screen
{
================================================================================
Customer Number: [c1          ]    Company: [c4                    ]

ORDER INFORMATION
    Order Number: [o11           ] Order Date:  [o12        ]

    Stock Number: [i13       ]   Manufacturer:  [i16  ]
     Description: [s14           ]              [m17              ]
            Unit: [s16           ]
                                      Quantity:  [i18          ]
                                    Unit Price:  [s15               ]
                                   Total Price:  [i19               ]

SHIPPING INFORMATION
  Customer P. O.: [o20         ]   Ship Charge:  [d1       ]

         Backlog: [a]       Total Order Amount:  [d2       ]
       Ship Date: [o21       ]
       Date Paid: [o22       ]
    Instructions: [23                                              ]
}
end

tables

customer
items
stock
orders
manufact

attributes
c1 = *customer.customer_num
   = orders.customer_num;
c2 = fname,
     comments = "Please enter initial if available";
c3 = lname;
c4 = company, reverse;
c5 = address1;
c6 = address2;
c7 = city;
c8 = state, upshift, autonext,
     include = ("CA","OR","WA","NV","AZ"),
     default = "CA";
c9 = zipcode, autonext;
c10 = phone, picture = "###-###-####";
o11 = *orders.order.num = items.order.num;
o12 = order_date, default = today, format = "mm/dd/yyyy";
i13 = items.stock.num;
    = *stock.stock.num, noentry, noupdate, queryclear;
i16 = items.manu.code, lookup m17 = manufact.manu.name joining
      *manufact.manu.code, upshift, autonext;
      = *stock.manu.code, noentry, noupdate, upshift, autonext,
     queryclear;
s14 = stock.description, noentry, noupdate;
s16 = stock.unit_descr, noentry, noupdate;
s15 = stock.unit_price, noentry, noupdate;
```

Listing 1. *(Continued on page 30)*

Revelation screen generator is harder to master with than that of R:base, Revelation's can be substantially more powerful without requiring the developer to resort to code.

Although Revelation screens are limited to operations on one table at a time, this limitation is easily bypassed without resorting to code. Each field represented on the screen (including calculated fields that may be the result of elaborate operations performed by functions stored in the data dictionary) can be customized in 26 ways.

Customizations include default values, enumerations, ranges, masks, automatic referential integrity checking, and the triggering of procedural subroutines and other screens that may address different tables. This last capacity applies not only to each field in the screen but to the screen as a whole, and includes the ability to signal the triggering of subprocedures:

If a specific field has changed...
If a specific field has not changed...
If anything (or nothing) has changed on the screen...
Unconditionally....

Triggered subprocedures can perform operations on all tables in the Revelation data base.

Data Access Corp.'s DataFlex is one of the easier screen generators to get started with and can be very powerful when used by a competent DataFlex programmer. Using a word processor, the designer creates a screen of a series of literal prompts and underscores that represent the windows where data will be displayed or entered to the data base. Once the screen template has been created, a utility program prompts the operator to name each attribute to be displayed in each position (up to 10 tables can be manipulated opened concurrently, but not in the initial creation of a screen).

The output of this utility program is a high-level procedural code compiled and run by the DataFlex run-time system. This code contains built-in functions such as cursor handling and data editing, insert, update, and delete, all of which can be selectively disabled by the programmer. DataFlex's screen generator generates entry code for one table at a time and creates the data table at the same time as the screen. This means a developer cannot use the screen generator to produce a new screen for an existing table.

However, these unfortunate by-products of the generation process can easily be circumvented. The screen and its associated code can be modified with most word processors and editors, and the out-

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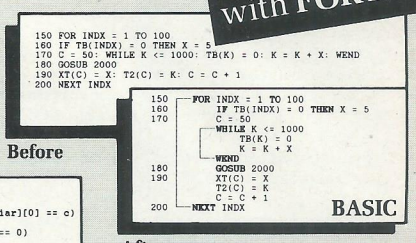

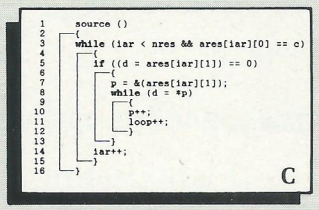

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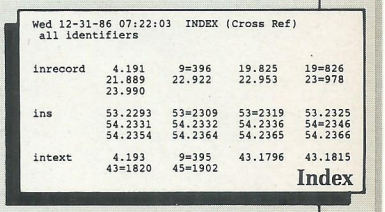

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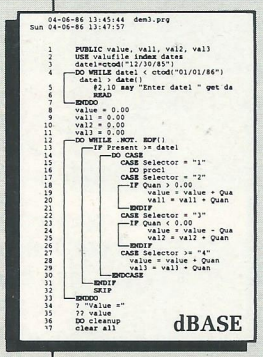

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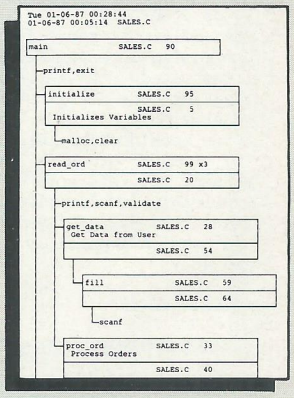

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CIRCLE 22 ON READER SERVICE CARD

```
i18 = items.quantity, include = (1 through 50),
      comments = "Acceptable values are 1 through 50";
i19 = items.total_price;
o20 = po_num, required,
      comments = "If no P.O. No. enter name of caller";
a = backlog, autonext;
o21 = ship_date, default = today, format = "mm/dd/yyyy";
o22 = paid_date, format = "mm/dd/yyyy";
o23 = ship_instruct;
d1 = displayonly type money;
d2 = displayonly type money;

instructions

customer master of orders;
orders master of items;
composites <items.stock_num, items.manu_code>
           *<stock_stock_num, stock.manu_code>

before editadd editupdate of orders
   nextfield = o20

before editadd editupdate of items
   nextfield = i13

after editadd editupdate of quantity
   let i19 = i18 * s15
   nextfield = o11

after add update query of items
  if (total of i19) <= 100 then
    let d1 = 7.50
    else
    let d1 = (total of i19) * .04

  let d2 = (total of i19) + d1

after display of orders
   let d1 = 0
   let d2 = 0

end
```

Listing 1. *(Continued from page 28)*

```
Output of the DataFlex screen generator with customizations.  The
designed screen is entered using any text editor as a template
between the "/SENSITIVE_INFO" and "/*."  Since the main file
addressed is "CUSTOMERS", the generator produces the "OPEN"
statement on line 1 and the "ENTRY" statements between lines 6
and 16.  The rest of the code is added by the programmer,
including all of the special action requirements shown in "[]" in
lines 7 thru 17.
The additional macro facilities made available for special
processing on save, delete, edit, clear, etc. are also
illustrated.  "ENTER.SAVE" is fleshed out a bit with lower-level
DataFlex code to illustrate the capacity to mix third and fourth
generation constructs, as is the "ACCEPT" statement on line 17,
which goes nowhere but is used to direct the activity of the
"ENTER.SAVE" group on lines 19 thru 30.  The line numbers are
present for reference only.  Note that there is no code
explicitly for functions like "clear," "save," and "delete."
These keys are assigned by the developer when installing DataFlex
and handled implicitly by the ENTER/ENTEREND macro loop (lines 6
and 48).

/SENSITIVE_INFO

        ORDER DATE: __/__/__

   Customer Number: _________       Customer Name
                                          First: ____________________
                                           M.I.: _
                                           Last: ____________________


   Outstanding Credit Limit: _______.__
   Total Business Last Six Months: _________.__
   Total Payments Last Six Months: _________.__
   Current Month Order Total: _______.__

   ORDER O.K.? _  ____________________________________________
/* // End of Screen Template
```

Listing 2. *(Continued on page 32)*

put of multiple runs can be concatenated in one multiscreen file set with the same editing tools and then compiled.

DataFlex's output is a collection of macro statements expanded into a run-time script code, then pseudocompiled with a fast run-time interpreter. The DataFlex macro language constitutes a fourth generation procedural language in its own right. These statements can be duplicated in a lower-level procedural language supported by the same compiler, giving the programmer more control responsibility. Developers can extend the macro language with constructs built in the lower-level syntax.

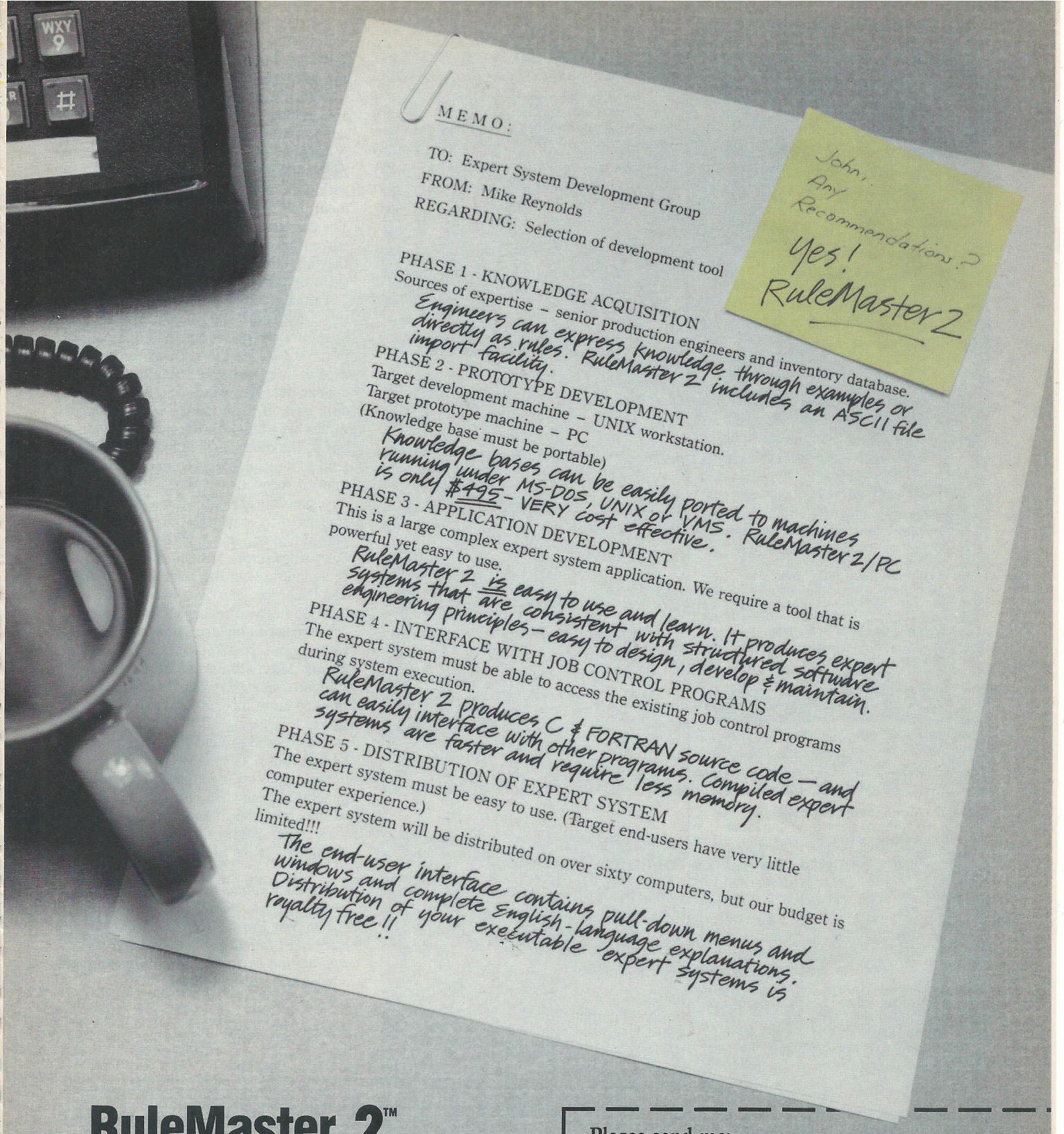
The high-level output of the screen generator includes escape's from the main entry portion of the resulting program in the form of the *ENTER.SAVE, ENTER.EXIT, ENTER.DELETE,* and other such statement groups. For example, just before a data base record is updated, statements in the *ENTER.SAVE* subsection of the program will be executed. These might extend to hundreds of lines of DataFlex procedural code in either the macro or the lower-level language (mixing the two is tricky), performing various operations on other files in the data base.

Using either level of the DataFlex language requires some programming skill, similar to d:BASE III Plus. Screens addressed by the code continue to be produced by a two-dimensional mapping process of editing a screen image and compiling it into the top of the program module most closely associated with the screen. Listing 2 is an example of the output of the DataFlex screen generation process.

While screen generators first appeared as part of microcomputer-based DBMSs, they are now associated with many third generation languages. These products allow programmers to paint a screen using a technique similar to R:base or DataFlex and turn the screen into its equivalent in third generation code (for example, COBOL, BASIC, or C). The main difference between these products and the screen generators of the DBMSs is that these products cannot automatically associate a screen window or field with a particular file or field from a table.

Cincom's Mantis screen generator is like a general-purpose screen generator, with a few interesting twists. Mantis is a high-level procedural and interpreted language that runs under CICS on IBM mainframes and Digital Equipment Corp.'s VMS on Vaxen.

The Mantis screen generator allows a designer to paint a screen and set up certain parameters for acceptable values in each field (these facilities are limited compared to those of R:base, Informix, or Revelation). It allows a designer to specify a number of buffers for a screen



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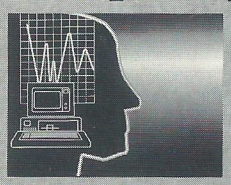

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CL

```
1  OPEN CUSTOMER
2  OPEN ORDERS
3
4  TODAYS_DATE=TODAY()
5
6  ENTER CUSTOMER
7    ENTRY X.ODR_DATE      [NOENTRY]
8    ENTRY X.CUST_NBR      [CAPSLOCK,AUTOFIND,FINDREQ]
9    ENTRY X.ACTV_ODR_NBR  [REQUIRED]
10   ENTRY X.LAST          [NOENTRY]
11   ENTRY X.MI            [NOENTRY]
12   ENTRY X.FIRST         [NOENTRY]
13   ENTRY X.CRDT_LMT      [NOENTRY]
14   ENTRY X.SIX_MO_TOT    [NOENTRY]
15  ENTRY X.SIX_MO_PD      [NOENTRY]
16  ENTRY X.CUR_MO_TOT     [NOENTRY]
17  ACCEPT WINDOW.10       [CAPSLOCK,CHECK="YN",REQUIRED]
18
19 ENTER.SAVE
20   IF SENSITIVE_INFO.10 EQ "Y"
21     ORDERS.ODR_NBR=X.OPER_ODR_NBR
22     FIND ORDERS BY INDEX.1
23     [FOUND] BEGIN
24        MOVE SENSITIVE.INFO.10 TO ORDERS.OK_FLAG
25        MOVE TODAYS_DATE TO ORDERS.OK_DATE
26        SAVE ORDERS
27     END
28     [FINDERR] MOVE "CANNOT LOCATE PROPER ORDER" TO SENSITIVE_INFO.11
29     CLEAR ORDERS
30  RETURN
31
32  ENTER.DELETE
33  // commands executed upon delete request...
34  RETURN
35
36  ENTER.EDIT
37  // commands executed upon edit or delete request...
38  RETURN
39
40  ENTER.CLEAR
42  // commands executed upon a clear screen request
43  RETURN
44
45  ENTER.EXIT
46  // commands to execute upon exiting the entry screen...
47  RETURN
48  ENTEREND
49  ABORT

        *                   *                   *
```

Listing 2. *(Continued from page 30)*

Products mentioned in this column

DataFlex
Data Access Corp.
14000 S.W. 119 Ave.
Miami, Fla. 33186
(305) 238-0012

Informix
Informix Software Inc.
4100 Bohanon Drive
Menlo Park, Calif. 94025
(415) 322-4100

Mantis
Cincom Systems Inc.
2300 Montana Ave.
Cincinnati, Ohio 45211
(513) 662-2300

Paradox
Ansa Software
1301 Shore Way Rd. Ste. 221
Belmont, Calif. 94002
(415) 595-4469

R:Base System V
Microrim
3925 159th Ave. N.E.
Redmond, Wash. 98052
(206) 885-2000

Reflex
Borland International
4584 Scotts Valley Dr.
Scotts Valley, Calif. 95066
(408) 438-8400

UNIFY
Unify Corp.
3870 Rosin Ct.
Sacramento, Calif. 95834
(916) 920-9092

field where multiple records of a table can be displayed at the same time.

Mantis's generated screen is named in a procedure that references it with a screen statement, *SCREEN LOCAL.NAME(LIBRARY:LIBRARY.NAME, LIBRARY.PASSWORD)*. It is used within the procedure via a converse statement, *CONVERSE LOCAL.NAME*. The converse instantly displays all of the current values for the screen fields as they are stored in the buffers set up for them by the screen generator.

Values must be moved to and from these fields with the usual assignment operators unless the names of the fields in the screen are the same as those of the external view or views being used to exchange data between the screen and the data base. If these names are the same, values are automatically mapped from one to the other. This mapping can extend to multiple views from one screen or many screens to one view.

A procedural program may have many screens in its map set, which can be displayed like pop-down or tile-style windows since screen size (lines by columns) is configurable in the generation process and the screen can be conversed at any location in the physical screen space.

Screens can be larger than the physical screen (up to 250 lines by 250 columns). Mantis comes equipped with standard, single-keystroke scrolling options so large reports can be displayed on line in a large logical page that the operator can scroll around for query or update purposes.

Next month I'll compare some report generators, and then begin to explore the various procedural languages associated with contemporary DBMS products and the design issues they raise.

Matthew Rapaport is currently employed by the AMEX Life Assurance Co. in San Rafael, Calif., and has worked in fourth generation language application environment development for six years.

MICROSOFT LANGUAGES NEWSLETTER VOL. 2, NO. 11

Dear Reader:

When we introduced the Microsoft® Languages Newsletter in 1985, we had just one goal in mind: improving communications with the people who use Microsoft languages.

We wanted to communicate to you the technical advances underway at Microsoft and get feedback from you about how we could make additional improvements to our products.

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We know that in order to make this vision come true, we need to supply you with effective development tools—such as the Microsoft CodeView® debugger, Microsoft QuickBASIC and QuickC™ programming languages, and Microsoft C Optimizing Compiler.

But we also know that we need your help to achieve our vision of the future. That's why, back in January, we asked you to share your visions of the ideal programming environment. Your response was tremendous. In fact, we're already exploring many of your ideas, including language enhancements to support windowing environments, a general programmer's editor, and a "super" MAKE facility.

These are just a few examples of how your ideas and suggestions have helped us shape our future product plans. From the very beginning of the Languages Newsletter, your feedback has been invaluable. And that's why we want you to be part of some important changes.

As we look to the next couple of years, we recognize that developers will want to create more global solutions; solutions that will encompass languages, operating environments, and networking. With that in mind, we have decided to transfer our resources from the Languages Newsletter to the Microsoft Systems Journal*—a bimonthly publication covering the broad scope of systems-related issues.*

Because the Microsoft Systems Journal *will include much of the information you're used to getting from the Languages Newsletter, and because we value your active participation in shaping future products, we'd like to offer you a free issue of the* Microsoft Systems Journal.

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Pattern Matching Alternatives:

Theory vs. Practice

By Jack Purdum

Sooner or later, every programmer needs a routine that searches a large sequence of characters (perhaps an array or a file) for a match on a specific character pattern. I've needed such a routine many times over the years but never seemed to have the time to investigate the problem properly. I would just hack a brute force solution together until it worked. The old adage "If it ain't broke, don't fix it" tended to rule things.

Some time ago, I found need for such a routine again. This time, however, I thought I'd dig around for something a little more sophisticated than my earlier brute force algorithms. Although several algorithms could be used, I implemented three in C and performed some simple tests to evaluate their relative performance.

In the course of my search, I found an excellent article by Richard Wiggins and Paul Wolberg on string searching using the Boyer-Moore algorithm ("Searching for Strings with Boyer-Moore," *COMPUTER LANGUAGE,* Nov. 1986, pp. 28-42). Wolberg was kind enough to send me his C translation of code used in that article, and some of Wiggins' and Wolberg's work is presented here. However, I cannot do justice to their in-depth explanation of the Boyer-Moore algorithm. You owe it to yourself to read the article.

The remainder of this article presents an idea or two designed to wring a little more performance from the algorithms studied. The results of those efforts are also discussed.

Algorithms tested

There is a wealth of information on string searching. Many algorithms could have been selected for the comparison in this article, but I tested only three: Knuth-Morris-Pratt, brute force, and Boyer-Moore.

It became obvious at an early stage in the testing that the Knuth-Morris-Pratt algorithm could not beat Boyer-Moore in performance on any reasonable pattern. For the patterns tested, Boyer-Moore was at least twice as fast and in some cases beat Knuth-Morris-Pratt by a factor of 9. (If you are interested in knowing more about the Knuth-Morris-Pratt algorithm, a good discussion is found in

Robert Sedgewick's *Algorithms*, Addison-Wesley, 1984, pp. 241-254. Chapter 19 of this book is especially useful.)

Using brute force

Because I had always used brute force for pattern matching in the past, the brute force algorithm is presented as a basis from which the performance of the other algorithms is measured.

A brute force approach to string searching involves simply looking at each character in the string and comparing it to the first character in the pattern. If the first character matches, the next character in the string is compared against the next character in the pattern. Eventually, you either force your way through the string or find a match on the pattern.

As was pointed out in the Wiggins and Wolberg article, the brute force algorithm is a function of the number of characters in the pattern (m) and the number of characters in the string being searched (proportional to $m*n$). Textbooks often present the theoretical timing function for a brute force search algorithm as $O(m*n)$. This approach obviously suggests that the brute force algorithm degrades as m and/or n increase.

The first version of the brute force algorithm is the one used by Wiggins and Wolberg to gauge the performance of the Boyer-Moore algorithm. Their code appears in Listing 1. Most of the original comments have been stripped from the code. Even so, the code is pretty easy to understand.

The Wiggins and Wolberg brute force algorithm (called WWBF from now on) is based upon the assumption that *MAXLINE* lines of text of *MAXSTR* length are read into the character array to be searched (*Target*). Variable *NumFound* keeps track of the number of matches located in the search string.

The *posBF()* function does the real work. The brute force algorithm simply looks at a character in the target string and tests for a match on the first character in the pattern being searched. If the character in the target string matches the first character in the pattern, a second *for* loop checks for additional matches between the target and pattern strings. If we continue in the inner *for* loop *Patlen*−*1* times, we have a match, and *posBF()* returns the index into the target string.

Because I needed a memory-based pattern algorithm on data that might not contain any *newline* characters in the file, my test code differed from that used by Wiggins and Wolberg. Also, their test code is designed to count the number of matches found in a file.

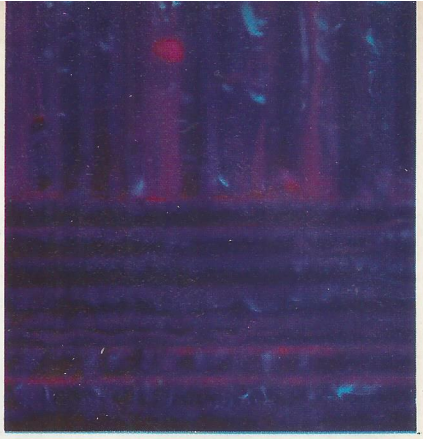
My design goal was to get a pointer to the match, if one is found. I modified Wiggins' and Wolberg's code to return pointers and then tested their brute force implementation using my test data files. In my version of the test code, a data file is opened, its size determined, and then

```
Wiggins-Wolberg brute force

/*
        TargetList -- an array of strings to search.
*         NumLines -- the number of elements in Target.
*          Pattern -- the pattern to search for.
*/
DoBruteForce(TargetList, NumLines, Pattern, NumFound)
char TargetList[MAXLINE][MAXSTR+1];
int NumLines;
char Pattern[];
int *NumFound;
{
     int  PBF;  /* Position of Pattern in Target
                   as returned by posBF */
     int  i;    /* Loop counter */
     for (i = 0; i <= NumLines; i++) {
        PBF = posBF(TargetList[i], Pattern);
        if (PBF > 0){
           (*NumFound)++;
        }
     }
}
posBF(Target, Pattern)
char Target[];   /* String to search. */
char Pattern[];  /* String to search for. */
{
     int  Stop;   /* The last position in Target
                     to look for Pattern */
     int  i;      /* The current position in Target for search */
     int  j;      /* The current position in Pattern being compared
                     to the corresponding position in Target */
     int  Patlen;
     Patlen = strlen(Pattern);
     Stop = strlen(Target) - Patlen;
     for (i = 0; i <= Stop; i++){
        for (j = 0; Pattern[j] == Target[i + j]; j++){
           if (j == Patlen-1) return(i+1);
        }                                    /* end for j */
     }                                       /* end for i */
     return(0);
}
```

Listing 1.

```
Modified WWBF algorithm

/*
*********************************************************************
*                    D O B R U T E F O R C E
      Code supplied by Paul Wolberg. Modified by JJP to return
      a pointer to match or NULL if no match.
*********************************************************************/
char  *DoBruteForce(char Target[], char Pattern[], int n)
{
   int Patlen,     /* The length of Pattern */
       i,          /* The current position in Target for search */
       j;          /* The current position in Pattern compared
                      to the corresponding position in Target */
   Patlen = strlen(Pattern);
   i = 0;
   for (;;){
       if (Pattern[0] == Target[i]) {
          if (strncmp(Pattern, &Target[i], Patlen) == 0)
             break;
       }
       i++;
   }
   if (i > n - Patlen) {
      return NULL;              /* Pattern not found in Target. */
   } else {
      return &Target[i];
   }
}
```

Listing 2.



enough memory dynamically allocated to read the file into memory. As explained in the next section, I also modified the algorithm to use a sentinel value in the search process. (More on sentinels in a moment.)

The test environment was an AT-type machine running at 7.2 MHz with no wait states. All code was compiled with the Ecosoft Eco-C88 C compiler, although any C compiler should handle the code with little or no modification.

Due to the resolution of the system clock, each search is repeated 100 times. That is, we search for a pattern in a file 100 times to get the times high enough so we can use the MS-DOS system clock for timings. All of the test files are approximately 27.3K in length, and the search patterns are the last item in the file. That is, if we are going to search for the name Mary, we will look through approximately 27.3K of text before finding a match. Therefore, the timings are based upon searching about 2.73MB of text with each of the algorithms tested.

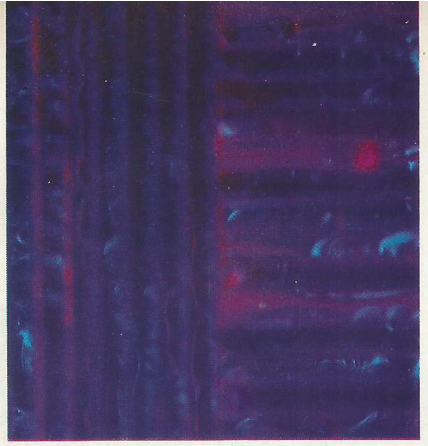
Sentinels

After modifying the WWBF algorithm for use with my testing scheme, the test time on one of the data files was about 41 seconds. I then changed Wiggins' and Wolberg's code slightly, as shown in Listing 2.

The careful reader might look at Listing 2 and say it won't always work properly because the function does not check to see if there are any more characters to search in the *Target[]* character array. Well, you're sorta right.

What is not obvious is the use of what is called a sentinel. The program devised to test the algorithms (Listing 3) first asks for the pattern to be searched for or *Pattern[]* in the argument list for the brute force search.

Next, the program finds out how large the test file is (three files were used for testing each algorithm). The program then requests sufficient storage to hold the entire file in memory *plus* a copy of the pattern string being searched. The program then reads the file into memory and adds the pattern string to the end of the file in memory. This copy of the



search pattern at the end of the file is called the sentinel.

Think about what the sentinel does for us. We now know with certainty that any search will at least find a match on the sentinel that's been added at the end of the text file. In most algorithms, this means we can eliminate the test to see if we have searched the entire text string. In our test procedure, using the sentinel saves about 2.73 million comparisons. A million here, a million there...they all add up.

Only one problem remains: we must be able to distinguish between a match on the sentinel and a "real" match in the text being searched. The problem is easily solved: if the match occurs after looking at more than *strlen(Target)* characters, we know the match was on the sentinel. If you look at how the return values are determined in the function, you will see how we detect whether we match on the sentinel or on a real match:

```
if (i > n - Patlen) {
   return NULL;   /*Pattern not in Target*/
} else {
   return &Target[i];
}
```

If *i* is greater than the length of the search string minus the length of the pattern, we matched on the sentinel value rather than a pattern in the target string. Therefore, we return a *NULL* pointer to indicate no match. Otherwise, we found a real match in the string and return a pointer that points to the match in the target string.

Two other changes appear in Listing 2. First, we removed the overhead associated with a function call by moving the WWBF *posBF()* function call into *DoBruteForce()*. Second, we used the standard library function *strncmp()* to perform the check for a pattern match. This allows us to remove one *for* loop and let *strncmp()* do most of the work. As a result of the changes reflected in Listing 2, one of the search times decreased from 41 seconds to less than 28 seconds.

The row labeled "Modified WWBF"

C source code for test program

```
#include <stdio.h
#include <string.h>
#include <malloc.h>

#define MAXCHAR 129

#ifndef TRUE
   #define TRUE    1
#endif

char *getmemory();
long clock(), dosize();
void copyfile(), dofile(), dotest();

FILE *fp;

int main(int argc, char **argv)
{
   char pat[MAXCHAR], *ptr, *start;
   int big, i, m, n, next, which;
   unsigned int total;
   long b;

   total = getpat(pat);                    /* Get pattern and length     */
   dofile(argv);                           /* Open the file--set fp      */
   b = dosize();                           /* How big is the file        */
   total += (unsigned) b + 1;              /* Enough for file + pattern  */
   start = ptr = getmemory(total);         /* Get the memory             */
   copyfile(ptr, pat);                     /* Copy file to memory        */
   ptr = start;
   which = select();                       /* Which test                 */
   dotest(start, pat, which, (int) b); /* Run a test        */
}
/*************************************************************
                        dotest()
      Find out which test to run and run it.
Args:
      char *start = start of characters to be searched.
            *pat = pattern to look for
        int which = which test to run.
              big = size of the file.
Return value:
      none.
*************************************************************/
void dotest(char *start, char *pat, int which, int big)
{
   char *brut(), *brut2(), *boy_m(), *kmp(), *DoDelta2(), *DoDelta1();
   char *ptr, *DoBruteForce();
   int i;
   long t;
   double time;
   switch(which) {
      case 1:                          /* Sedgewick's Boyer-Moore */
         clock();
         for (i = 0; i < 100; i++)
            ptr = boy_m(start, pat, big);
         t = clock();
         break;
      case 2:                          /* Fast brute force */
         clock();
         for (i = 0; i < 100; i++)
            ptr = brut(start,  pat, big);
         t = clock();
         break;
      case 3:                 /* Wiggins and Wolberg brute force */
         clock();
         for (i = 0; i < 100; i++)
            ptr = DoBruteForce(start, pat, big);
         t = clock();
         break;
      case 4:                          /* WWBM with Delta2 */
         clock();
         for (i = 0; i < 100; i++)
            ptr = DoDelta2(start, pat, big);
         t = clock();
         break;
      default:
         t = 0L;
         break;
```

Listing 3. *(Continued on page 38.)*

```
    }
    time = (double) t / 1000000.0;      /* Get down to seconds */
    if (ptr == NULL)
       printf("No match.");
    else
       printf("\n\nptr=%s", ptr);
    cursor(22, 10);
    printf("Search Complete. Time = %g sec (%ld clock ticks)", time, t);
}
/*************************************************************
                          select()
      Which test will be run.
Args:          void
Return value:  int  selection value.
*************************************************************/
int select(void)
{
    char buff[10];
    int i;

    clrscr();
    printf("                    Which test:\n\n");
    printf("1. Sedgewick's B-M   2. Brute Force, V.2      3.W-WBF     ");
    printf("4. W-W w/Delta2\n");
    for (;;) {
        printf("\nEnter choice: ");
        i = atoi(gets(buff));
        if (i > 0 && i < 5)
           break;
        else
           printf("\a");
    }
    return i;
}
/*************************************************************
                              copyfile()
      Copy test file into memory. Note a sentinel copy is also
    added.
Args:          char *ptr = where the file goes in memory.
               *pat = the pattern to locate.
Return value:  none.
*************************************************************/
void copyfile(char *ptr, char *pat)
{
    int i;

    while ((i = fgetc(fp)) != EOF) {    /* Copy file to memory  */
       *ptr++ = i;
    }
    for (i = 0; pat[i]; i++)            /* Add sentinel at end  */
       *(ptr + i) = pat[i];             /* See text.            */
    fclose(fp);
}
/*************************************************************
                            getmemory()
      Get some memory from the op system.
Args:          int t = number of bytes needed.

Return value:  char * -- a pointer to t bytes of memory.
*************************************************************/
char *getmemory(int t)
{
    char *ptr;
    ptr = calloc(t, sizeof(char));
    if (ptr == NULL) {
       printf("Not enough memory");
       exit(1);
    }
    return (ptr);
}
```

Listing 3. *(Continued on page 39.)*

in Table 1 uses the code from Listing 2 as the basis for testing.

All of the algorithms implement a sentinel. I did this because the sentinel didn't affect my design goals, was easy to code, added very little overhead, and reduced the search time by about 20% in most cases. Also, it is not difficult to remove the sentinel if desired.

Brute force, version 2

Flushed with the success of the modified WWBF algorithm, I tried to think of more efficient ways to implement the brute force algorithm. After some trial-and-error fiddling, the code in Listing 4 emerged.

The primary difference between WWBF and version 2 is the use of the *memchr()* and *memcmp()* functions. Many C compilers have these functions (the functions are part of both UNIX System V and the pending ANSI X3J11 definition for the standard C library). The advantage of these functions is that they are faster than their *str* counterparts *strchr()* and *strncmp()* because they are simple and do less work (they don't know about nulls or anything else).

The *memchr()* function is designed to examine up to *n* characters for a match between the character pointed to by *t* and *p*. If a match is found, *memcmp()* is called using the pointer returned by *memchr()* as the index into the target string and comparing it with the pattern string pointed to by *p*. The *memcmp()* function then examines *n* (the pattern length) characters to see if a match is found. If a match is found, we break out of the infinite *for* loop, check for a real match vs. the sentinel, and return the appropriate pointer. If no match is found by *memcmp()*, we up the pointer in the target string and continue looking. Ultimately, we must either find a match or the sentinel and appropriate pointer is returned.

Version 2 of the brute force algorithm reduced the test time to just under 3.5 seconds. We now have an implementation of the brute force algorithm that is simple to understand, uses standard C library routines (so it should be fairly portable), has pretty small code size, and is

over 10 times faster than our original version. The brute force presented in Listing 4 appears as the last row in Table 1.

Boyer-Moore, version 1

There is little room to improve on the discussion of the Boyer-Moore algorithm as presented by Wiggins and Wolberg. I encourage the reader to study their examples.

One important distinction pointed out in the Wiggins and Wolberg article is the linearity of Boyer-Moore. That is, its performance is a function of $m+n$ rather than $m*n$, as was the case for the brute force algorithm (a theoretical timing function of $O(m+n)$). What follows in this section is just enough information to give you some idea of how the algorithm works.

The Boyer-Moore algorithm decides where to continue searching based on any mismatch on the last character of the pattern and the string being searched. For example, if we are looking for the pattern hooli in the sentence:

```
hoola hoola girls like hoopla and hooligans.
(1) hooli
(2)    hooli
(3)     hooli
```

the mismatch is on the a in hoola and the i in hooli. Upon finding a mismatch, the

```
/*****************************************************************
                            dosize()
      How large is disk file? Need for dynamic memory allocation.
Args:          none.
Return value:  long -- size of data file to be read into memory.
*****************************************************************/
long dosize(void)
{
   long b;
   fseek(fp, 0L, 2);                /* Go to end of file    */
   b = ftell(fp);                   /* See how big it is    */
   fseek(fp, 0L, 0);                /* Rewind to the start  */
   return (b);
}
/*****************************************************************
                            dofile()
      Open a disk file. Note use of binary flag to get around
      carriage-return line-feed adjustments.
Args:          int argv = name of file from the command line.
Return value:  none.
*****************************************************************/
void dofile(char **argv)
{
   if ((fp = fopen(argv[1], "rb")) == NULL) {
      printf("Can't open it.\n");
      exit(1);
   }
}
/*****************************************************************
                            getpat()
      What is the search pattern?
Args:          char *pat = character array for search pattern.
Return value:  int -- length of the search pattern.
*****************************************************************/
int getpat(char *pat)
{
   clrscr();
   printf("\n\nEnter search string: ");
   gets(pat);
   return ( strlen(pat) );
}
```

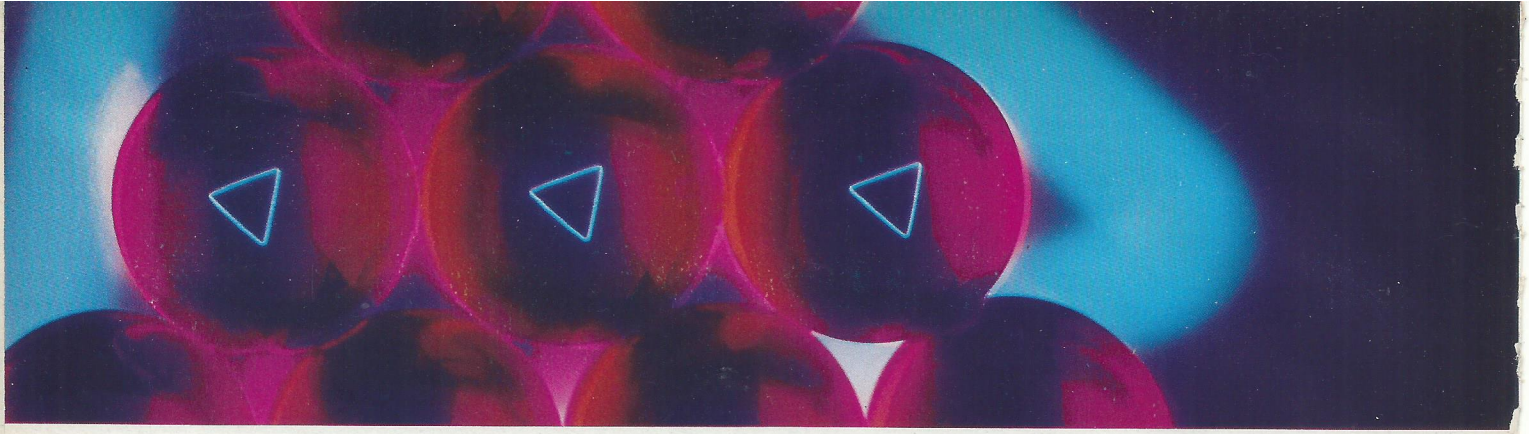
Listing 3. *(Continued from page 38.)*

Indexed test results (sec)

	Test										
Algorithm	Big Mary	Little Mary	abc	pabc	hooli	string	computer	table	zeeee	eeeeeeez	Average
Modified WWBF	39.9	39.7	80.9	41.3	53.6	41.0	41.2	41.4	39.9	30.4	44.9
Boyer-Moore, version 1	6.1	28.9	8.8	72.0	27.5	21.1	16.7	24.8	23.9	15.0	24.5
WWBM with Delta2	2.1[1]	7.3	2.7[1]	23.8	7.4[1]	5.5[1]	4.6[1]	6.9[1]	6.4	3.8[1]	7.1
Brute force, version 2	3.2	3.3[1]	14.8	3.2[1]	13.8	6.2	6.1	7.0	3.2[1]	7.8	6.9

1. Fastest time for the test.

Table 1.



algorithm reads an array (configured prior to the text search) to determine how many characters can be skipped in the string. Because the a is not duplicated elsewhere in the pattern string, we can skip five characters before trying another match. Therefore, the second text compares the l in the string with the i in the pattern. This time, however, we can only advance one position because of the l in the pattern.

In case 3, we again fail on the a in the string. Because the a does not appear in the pattern, we can advance *strlen(patern)* characters for the next test. Clearly, the Boyer-Moore algorithm is going to allow us to skip along quite fast through the text, especially if the last character (for example, a hyphen) in the pattern is not used very often in the string being searched or the last character of the pattern is not repeated in the pattern.

My first attempt at coding the Boyer-Moore algorithm (Listing 5) was taken from the algorithm presented in Sedgewick's text. Note how the *memset()* call is used to set all elements of the *delta1[]* array to the length of the pattern string. The *for* loop is then used to change only those elements that appear in the search string. The values in the *delta1[]* array determine how far we can safely skip in the target string if a match fails. Also note that we have added a sentinel, and the final *if* statement tells us if we have a real match or if we found the sentinel.

Note that the Boyer-Moore performance is significantly influenced by the pattern being searched. For example, the Big Mary test in Table 1 had the sentence "Mary had a little lamb whose fleece was white as snow." as the last item in the file. A search on just the word "Mary" took about 28.9 seconds, while a search on the entire sentence took only 6.2 seconds. Part of the improvement is because a search on the entire sentence is based on a period as the last character in the pattern, a character not replicated in the pattern string. This, plus the fact that the pattern is quite long, allows us to skip through the text string very rapidly. This is where Boyer-Moore shines: relatively large values for *m*.

I shall have more to say about pattern sensitivity in the section that discusses the test results. The code presented in Listing 5 is the Boyer-Moore version 1 that appears in Table 1.

```
Brute force, version 2

/*****************************************************************
                              brut()
     About as fast as we can do a dumb brute force search in C.

Args:              char a[] = string to search
                        p[] = pattern to search for in a[]
                     int n = length of a[].

Return value:      char *    a pointer to the match if found,
                             NULL if no match.
*****************************************************************/
char *brut(char a[], char p[], int n)
{
   char *ptr, *s;
   int m;
   s = a;
   m = strlen(p);
   for (;;) {
      if ((ptr = memchr(a, p[0], n)) == NULL)
         break;
      if (memcmp(ptr, p, m) == 0)
         break;
      a = ptr + 1;
   }
   return ((n - (ptr - s) <= 0) ? NULL : ptr);
}
```

Listing 4.

Boyer-Moore, version 2

The Wiggins and Wolberg article published a second version of the Boyer-Moore algorithm (Listing 6) that uses a second Delta table. While that article explains this refinement in detail, the purpose of the *delta2[]* array is to allow the largest skip value possible on a false match while ensuring that a match is not missed. Because the *delta2[]* array uses substrings to determine maximum skip values, this refinement performs best when the pattern string is repetitive.

Although I made some modifications to the code to conform to my testing procedure, the code shown in Listing 6 is essentially the code provided by Wolberg. While the authors were apologetic about the *GOTO*'s in their article, perhaps they shouldn't have been. I rewrote the code using infinite *for* loops and a sentinel and it actually ran slightly slower than their version. (Nobody said *GOTO*'s were inefficient.) Therefore, the code in Listing 5 is very true to the Wiggins and Wolberg implementation of Boyer-Moore, with the Delta2 refinement.

Test data

As already mentioned, the source code for the test program appears in Listing 3. The program allows the test file to be specified as part of the command line.

Three test files were built, each about 27,300 bytes long.

The first test file was several C source code programs added end-to-end with one line added as the last line in the file: "Mary had a little lamb whose fleece was white as snow." This sentence was the search pattern for the Big Mary test. A second test simply looked for the single word "Mary" and is called the Little Mary test.

The Mary test file also contains several common words added at the end of the file. These words were also part of the test results presented in the Wiggins and Wolberg article. Table 1 shows the words used.

The second file, the hooli test, contained the following sentence:

```
hoola hoola girls like hoopla and hoolagans.
```

repeated enough times to build a file of approximately 27,300 bytes in length. The last word in the file was then changed to hooligans (note the exchange of a for i). The search pattern for this test was hooli. This pattern was selected because it can have a fairly high number of false matches in the file. This file should favor the Boyer-Moore algorithm because it is a nonrepeating pattern within the pattern string and the text is highly repetitive.

The final test file, called the abc test, consisted of the pattern abcdefghijklm repeated enough times to build a 27,300-byte file. No *newline* characters appeared in the file. The last entry in the file had an n added to it. The search pattern was abcdefghijklmn. This file also has a high repeat factor and should favor the Boyer-Moore algorithm.

A spin-off of the abc test was to search for the pattern pabcdefghijklm. Because many matches would falsely start with the end of the pattern string before sensing the p, Boyer-Moore would be placed at a severe disadvantage. On the other hand, brute force version 2 should do very well because the only p in the file is the pattern itself. This test is called pabc. These two tests present a best-case, worst-case test of Boyer-Moore.

```
Boyer-Moore algorithm, version 1

/*****************************************************************
                                        boy_m()
    Boyer-Moore search based upon Sedgewick's algorithm.
Args:
   char a[] = string to search
      pat[] = pattern to search for in a[]
      int n = length of a[].

Return value:
   char * -- pointer to the match if found, NULL if no match.
*****************************************************************/
char *boy_m(char a[], char pat[], int n)
{
   unsigned char deltal[127];
   int j, offset;
   int c, i, m, term;
   m = strlen(pat);
   memset(deltal, (unsigned char) m, 127);
   for (j = 0, i = m - 1; i >= 0; i--, j++) {
      c = pat[i];
      if (deltal[c] == m)
         deltal[c] = j;
   }
   i = m - 1;
   j = m;
   while (TRUE) {
      if (a[i] == pat[j - 1]) {     /* If we have a match...   */
         i--;
         j--;
      } else {                      /* No match yet. March on  */
         i += m - j + 1;
         j = m;
         term = m - j + 1;
         offset = deltal[a[i]];
         if (offset > term) {
            i += offset - term;
         }
      }
      if (j < 1) {                  /* If j == 0; a match      */
         break;                     /* If i > n, no more string */
      }
  }
  if (i > n - m)                    /* Found sentinel   */
     return NULL;
  else
     return &a[i + 1];
}
```

Listing 5.

```
WWBM with Delta2

/*
*********************************************************************
*                          D O D E L T A 2

      Code supplied by Paul Wolberg. Modified by JJP to return
      a pointer to match or NULL if no match.
*********************************************************************/

char *DoDelta2(char Target[], char Pattern[], int n)
{
   char *posDel2();
   int Deltal[ASCIILEN+1],        /* The deltal table. */
       Delta2[MAXSTR+1],          /* The delta2 table. */
       patlen;                    /* Length of Pattern. */
   MakeDell(Pattern, Deltal);
   patlen = strlen(Pattern);
   Deltal[Pattern[patlen - 1]] = LARGE;
   MakeDel2(Pattern, Delta2);     /* Create the delta2 table. */
                                  /* ShowDel2(Pattern, Delta2); */
   return posDel2(Target, Pattern, Deltal, Delta2, n);
}
/*
*********************************************************************
*                          P O S D E L T A 2
*********************************************************************/
char *posDel2(char Target[], char Pattern[], int Deltal[],
                                             int Delta2[], int n)
{
   int Trglen,     /* The length of Target     */
       Patlen,     /* The length of Pattern    */
       j,          /* Loop counters            */
       hop;        /* Number of characters to move along
                      Target before next comparison.        */
   int i;
   Trglen = n;
   Patlen = strlen(Pattern);
   if (Patlen > Trglen)
      return (NULL);
   i = Patlen - 1;

FAST:
   i = i + Deltal[Target[i]];
   if (i > 0)
   if (i < LARGE)
      return (NULL);
   i = (i - LARGE) - 1;
   j = (Patlen - 1) - 1;

SLOW:
   if (j < 0 && i < n - Patlen)     /* Modified for sentinel   */
      return (&Target[i + 1]);
   if (Target[i] == Pattern[j]) {   /* Found match on character */
      j--;                          /* Get ready for next one */
      i--;
      goto SLOW;                    /* See if we've looked at all */
   }
   hop = Deltal[Target[i]];         /* No match. Set up skip value */
   if (hop == LARGE)
      hop = 0;
   if (hop > Delta2[j]) {           /* Which skip can we use? */
      i = i + hop;
   } else {
      i = i + Delta2[j];
   }
   if (i < Trglen){                 /* Have we looked at all?  */
      goto FAST;
   } else {
      return (NULL);
   }
}
```

Listing 6. *(Continued on page 43.)*

As you can see from the code in Listing 6, each test time is based on 100 complete searches of the file in memory for the pattern. Test times are an average of several runs using a *clock()* function for timing.

Fairness in testing

It can be argued that it is unfair to compare a brute force implementation using the *memchr()* and *memcmp()* functions because they are coded for speed (often in assembler) and are not part of the Boyer-Moore algorithm. One might further argue that the only fair comparison would be a brute force written in pure C.

Well, the tests aren't fair. My goal was to write a function capable of searching a string as quickly as possible given the resources at my disposal. In my mind, using efficient functions to accomplish a task makes sense. If this is unfair, so be it.

The results of the tests are shown in Table 1. The entries in the table are the number of seconds required to run 100 iterations of the search for each of the algorithms tested. The times should be viewed as good approximations since they are averages of several runs and are limited to the resolution of my system clock. However, the times do give an indication of the relative performance of the various algorithms tested.

The Big Mary test is on the string "Mary had a little lamb whose fleece was white as snow." while the Little Mary test is on the single word "Mary." All of the other tests are on the strings shown in Table 1.

The first thing you might notice is that the refinements to the first version of the brute force algorithm paid off. On average, the modified brute force is over seven times faster than the original version. Implementing a sentinel in the algorithm accounts for between 10% and 15% of the improvement.

In the Wiggins and Wolberg article, the largest difference between the brute force and Boyer-Moore algorithms was a search pattern of eeeeeeez, with Boyer-Moore winning by a factor of 10. With the new implementation, the difference is a factor of about 2. (Again, the results

are biased because of the sentinel used to improve performance.)

Next, notice that the Boyer-Moore algorithm outdistances the pack on the abc and hooli tests, both of which contain files with highly repetitive text sequences using nonrepetitive search patterns. Conversely, the algorithm does much worse on the pabc test using the same text file but a highly false search pattern. (A highly false search pattern would have matches on all characters in the pattern except the first.)

Also notice that Boyer-Moore does not do well on the zeeee test. This is due to the repetitive nature of the pattern and the high frequency of the letter e in text files.

The brute force version 2 performance is almost opposite that of Boyer-Moore on the unusual files. In particular, notice the performance difference on the pabc test. Brute force version 2 does well because there is only one p in the file so *memchr()* spins through the file very quickly. Boyer-Moore, on the other hand, has to execute a lot of false test code (because of matches on abcdefghijklm) before finding out it's not a match on the letter p.

It is important to notice that Boyer-Moore and brute force version 2 have very similar times on real words. When you consider 100 passes through a 27K text file, the time difference would go unnoticed on a single pass through a file.

And the winner is...

This exercise suggests several conclusions. First, I agree with Wiggins and Wolberg that the Boyer-Moore algorithm typically outperforms a brute force algorithm. You can, however, devise pernicious data sets to show either algorithm the winner.

Second, the time difference between the Boyer-Moore and brute force algorithms is very small in many cases. (This is especially true for my problem of finding one or two standard English words in a relatively small text file.)

Third, there is a big difference between the statement of an algorithm in pseudocode and its final implementation in a working language. Indeed, in several

```
/*
*********************************************************************
*                          M A K E D E L 1

      Code supplied by Paul Wolberg.
*********************************************************************/
void MakeDel1(char Pattern[], int Delta1[])
{
   int  Patlen,              /* The pattern length */
        i;                   /* a loop counter */
   Patlen = strlen(Pattern);
   for (i = 0; i <= ASCIILEN; i++) {
      Delta1[i] = Patlen;
   }
   for (i = 0; i < Patlen; i++)
      Delta1[Pattern[i]] = Patlen - (i + 1);
}
/*
*********************************************************************
*                          M A K E D E L 2
      Code supplied by Paul Wolberg.
*********************************************************************/
void MakeDel2(char Pattern[], int Delta2[])
{
   int k,
       patlen,       /* Length of Pattern. */
       rightend,     /* The array index pointing to last
                        character in Pattern. */
       patlen2,      /* Twice the length of Pattern. */
       j, j1, f[MAXSTR], f1[MAXSTR],
       q, q1, t, t1;
   patlen = strlen(Pattern);
   rightend = patlen - 1;
   patlen2 = 2 * patlen;
   for (k = 0; k <= rightend; k++) {
      Delta2[k] = patlen2 - (k+1);
   }
   j = rightend;
   t = rightend + 1;
   while (j >= 0) {
      f[j] = t;
      while ((t <= rightend) && (Pattern[j] != Pattern[t])) {
         if (rightend - j < Delta2[t])
            Delta2[t] = rightend - j;
         t = f[t];
      }                          /* end while ((t <= */
      t--;
      j--;
   }                                        /* while (j >= 0) */
   q = t;
   t = rightend - q;
   q1 = 0;
                     /* Section labeled B1 in Rytter's paper. */
   j1 = 0;
   t1 = -1;
   while (j1 <= t) {
     f1[j1] = t1;
     while ((t1 >= 0) && (Pattern[j1] != Pattern[t1])) {
        t1 = f1[t1];
     }
     t1++;
     j1++;
   }
   while (q < rightend) {
      for (k = q1; k <= q; k++) {
         if (rightend + q + 1 - k < Delta2[k])
            Delta2[k] = rightend + q + 1 - k;
      }
      q1 = q + 1;
      q = q + t - f1[t];
      t = f1[t];
   }
}
```

Listing 6. *(Continued from page 42.)*

cases in Table 1 the language is the same and the fundamental algorithm is similar, yet the two implementations differ in performance by a factor of 10 or more. Given that a good part of the performance difference stems from using different library functions, a related conclusion is that it pays to know what your standard C library has to offer in the way of alternatives.

At the beginning of this article, I reiterated the theoretical specifications (linear vs. quadratic) given in the Wiggins and Wolberg article for the algorithms tested. The terms linear and quadratic alone suggest that the times should be substantially different. Empirically, however, they are not. The reasons for this disparity are many, such as choice of language, resources at hand, and implementation of the algorithm.

There is another factor, however: "Can I as a programmer, given my skills and tools, implement a given algorithm in a way that meets its theoretical timings?" In theory I should be able to, but in fact I doubt that I could.

Programmers may overlook the fact that theoretical timings are functions for a given set of parameters. In most cases, the theoretical function is stated as $O(n+m)$ or $O(n*m)$. Because the theoretical times are stated in functional form, we tend to immediately assume that the latter is slower than the former. Not necessarily so.

We know, for example, that Boyer-Moore requires considerable set up time (for example, the Delta tables) before it can begin processing the string. The set up time for the brute force algorithm is virtually nil.

To illustrate what this implies, let's make the (simplifying) assumption that both functions are linear in form. Let's further assume that our (hypothetical) function for Boyer-Moore has the form:

```
time=500,000+.1(n+m)
```

The equation suggests that 500,000 units of time are spent setting things up for Boyer-Moore.

On the other hand, a (hypothetical) brute force function might look like:

```
time=300+.8(n*m)
```

While Boyer-Moore has a short process time (the .1 coefficient multiplied by the linear behavior for n and m), the relatively high constant term (500,000) due to the high set up time suggests the algorithm starts slowly and gets better as n and m increase.

On the other hand, brute force has a low set up time but loses performance proportionately as n and m increase. This means brute force starts fast (good for short patterns) and fades in the stretch (not very good for long strings). If you try a value of 1 for m and 100 for n in the equations just discussed, you will see why set up time it important.

For the previous example, it should be clear that a crossover point exists where the performance of one algorithm becomes better than the other. This crossover is shown in Figure 1.

If you assume that n is constant, you can concentrate on the length of the pattern (m) being searched. If the pattern has $m1$ or fewer characters, brute force outperforms Boyer-Moore. For patterns longer than $m1$ characters, Boyer-Moore will win.

In reality, the actual functions probably don't look anything like those assumed to construct Figure 1; exact specifications of a timing function for an algorithm are rarely given. This lack of specificity often means some form of algorithm testing is necessary to see which alternative best suits your given need. (I'm assuming the function will be executed often enough to make testing worthwhile.)

The point should be clear: assuming that one algorithm will outperform another by casual inspection of their theoretical timing functions may not always be correct. Knowledge of the specifics of the function are very important to the actual behavior experienced in the trenches. You may need to test the algorithm to get some feel for its performance in your application. What looks bad in theory may be exactly what you need in practice.

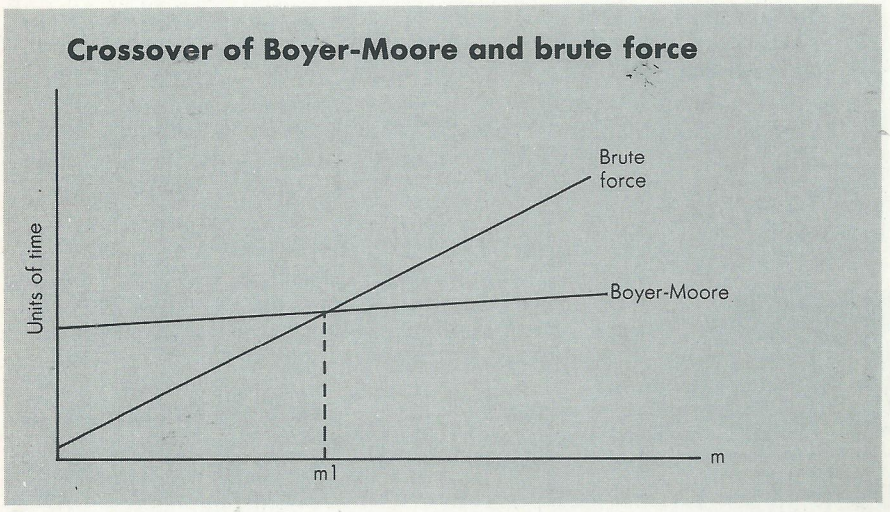
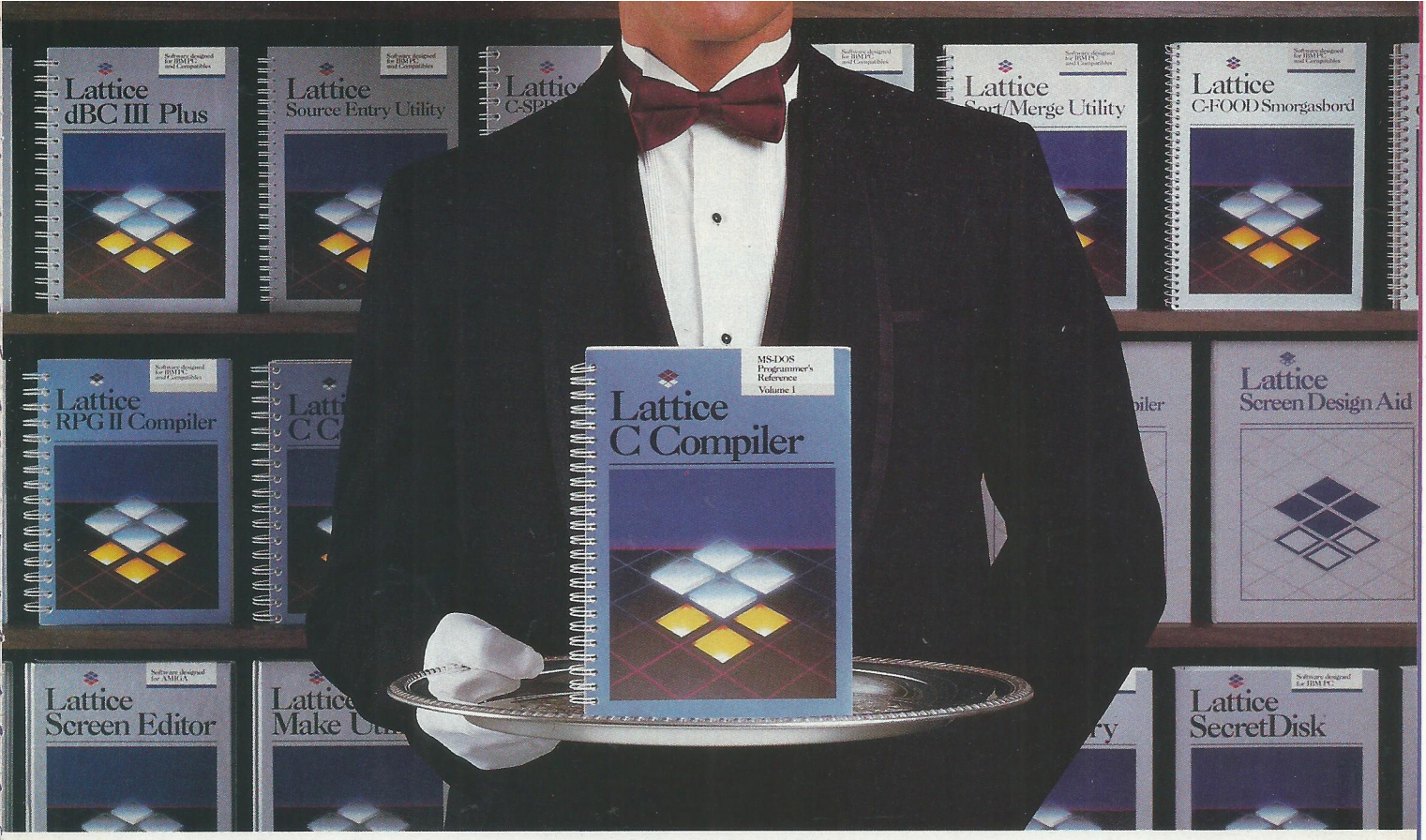


Figure 1.

Jack Purdum is a noted author of numerous C books, including C Programming Guide *and* Guide to the C Standard Library. *He is also the president of Ecosoft.*

Artwork: Anabella Gonzalez



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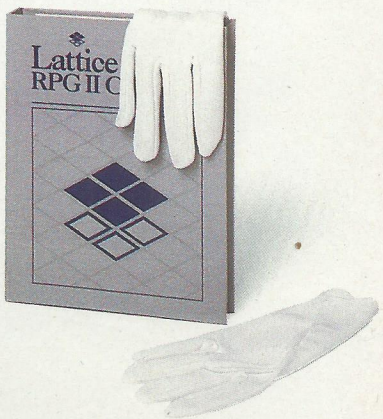

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Multiple Word Searches with LFIND

By E.J. Smith

The DOS *FIND* command can be used to search a text file for a word. Although the *FIND* command is fast, it has a few disadvantages: it is case sensitive (for example, *WRITELN* is not the same as *writeln*), and it can only search for a single word during its scan through the text file. When *FIND* locates the word, it does not indicate the line number in the file where the word was found.

The LFIND (List-find) program (Listing 1) described here accepts a list of words and searches for all of them in a single pass.

LFIND:

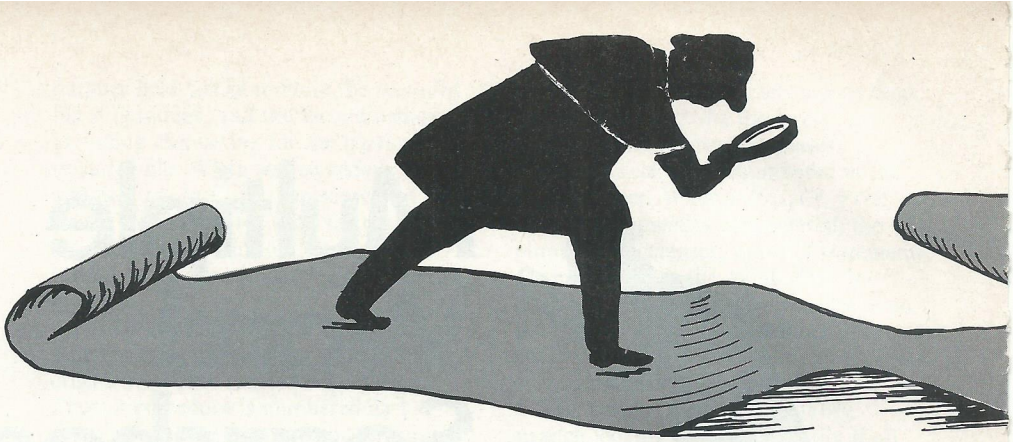
- Accepts multiple search words from a file
- Is not case sensitive
- Displays each line where a word is found
- Shows the line number of the text file
- Uses a very fast search algorithm

LFIND is written in Turbo Pascal v. 3.0 and the IBM Macro Assembler v. 2.0. The search algorithm is efficient and fast. When looking for a single word, LFIND is almost as fast as the DOS FIND command. But LFIND really comes into its own when looking for multiple words.

The search algorithm has a remarkable property: the search time is independent of the number of words sought. That is, the search takes the same amount of time whether the list contains one word, 10 words, or 50 words. The

```
program List_find ;
{ A fast, Multi-word Search Program }

  ... Excerpts of the code are included here.
  ... Access the COMPUTER LANGUAGE Bulletin Board Service or
CompuServe forum to obtain a complete listings.

var
  S_table = array[0..250, 0..63] of char;     { contains the state diagram }
  Words : array[1..150] of W_string ;                    { table of words }

{ Two assembly language routines: }
procedure X_STR(...);   external ;
procedure SEARCH(...);  external ;

procedure Initialize;
procedure Read_words;
procedure Sort_words;
procedure Open_text;
procedure Read_text;

procedure Gen_tables;
    { uses Words[] list to generate the S_table state table }
  var
    Table : integer;
    procedure Gen(Col, Row1, Row9 : integer);
      { internal proc, recursively generate table contents }
    var
      Ch1 : char;
      Ltb, Row5 : integer;
      Any_ok : boolean;

    begin                                                { internal proc }
      Ltb := Table;
      Table := Table+1;
      Max_table := Table;
      if Table > States then
        begin
          writeln(^g' Too many words/characters...cannot continue.');
          halt;
        end;
      Row5 := Row1;
      while Row5 <= Row9 do
        begin
          Ch1 := Words[Row1][Col];
          if Words[Row1][Col+1] = char(1)
          then
            begin                                { next char is Any-Char code }
              Any_ok := true;
              Words[Row1][0] := char(Col);       { ignore all after the '?' }
            end
```

Listing 1. *(Continued on page 48.)*



FIND command is faster when searching for one word, but for two or more LFIND is much better.

Many string-search algorithms have been published in computer magazines and algorithm reference books. A few years ago I was browsing through a Bell System publication and encountered a search algorithm that processed a list of words. But I have never seen this algorithm explained in a popular magazine. (The method uses, in part, a concept discussed by Michael R. Middlemas in "Transition Analysis: From One State to Another," COMPUTER LANGUAGE, Jan. 1987, pp. 31-36.)

Thinking about this novel search technique, I realized the 8086 has an ideal instruction for implementation. Like the algorithm, this instruction gets little use. The LFIND program uses this instruction in the implementation of the algorithm to achieve very rapid execution.

State-machine search

How is it possible that a search method can be equally fast when looking for 50 words as when looking for one word? The search is implemented using a state machine that is uniquely generated from the list of search words. The more words and characters in this list, the bigger the state machine becomes.

The overall size of the state machine does not have any affect on processing speed. All states are stored in RAM, and the program can jump quickly from one state to another.

During the search only one state is occupied at time, as determined by the characters encountered in the text file. Each new character means one state change. In effect, a pointer changes value based on incoming characters. A larger number of search words merely means the pointer can assume a wider range of values.

Let's assume we want to search a text file for occurrences of the words CAR, CAT?, DOG, and DUCK. (The ? character is a wildcard that means any ensuing character is accepted.) The state diagram for these words is shown in Figure 1.

The machine is set to state 0 at the first character of a word. C changes state 0 to state 1; similarly, D changes state 0 to state 4. Then, from state 1, A causes a change to state 2, and from state 4, U causes a change to state 7. And so on. Any other character abandons the state machine until a blank (b) character is encountered, which resets the machine to state 0. This reset-after-failure could be accomplished using the state machine itself, but a scan-until-blank loop is much faster.

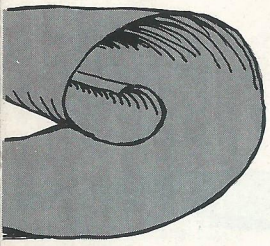
When a search word is found in the text, for example DUCKb, the state machine reaches the code for Hit that indicates a successful search. The line is then displayed on standard output along with its line number.

But this algorithm has a catch. It can only look for words, not strings. A word, as used here, is a string of alphameric characters that is preceded by white space. White space is anything that is not an alphameric character, such as a blank, tab, or carriage return character. For the state machine to work, it must be reset at the start of each word. For example, if CAT? is in the search list, we will get a hit on catalog or cat but not on bobcat.

The state diagram is useful in explaining how this search algorithm works. The next step is to implement it in a way that executes the search rapidly. The method used here trades memory for speed. A relatively large—and empty—table is

```
        else  Any_ok := false;
        repeat
          Row5 := Row5+1;
        until (Words[Row5][Col] <> Ch1)
        or (Row5 > Row9);
        Row5 := Row5-1;          { now points to 'bottom' of same-chr colm }
        if (Col > length(Words[Row1])) then
          begin
            if Row5 < Row9
              then  S_table[Ltb, Ø] := char(Bl_end)
              else  S_table[Ltb, ord(Ch1)] := char(Bl_next);
          end
        else
          if ((Row1 = Row5)
          and (Col = length(Words[Row1])))
          or (Col > length(Words[Row1]))
          or (Any_ok)
          then                                          { at End Of Word }
            begin
              if Any_ok
                then  S_table[Ltb, ord(Ch1)] := char(Any_next)
                else  S_table[Ltb, ord(Ch1)] := char(252);
            end
          else                                                { not EOW }
            begin
              S_table[Ltb, ord(Ch1)] := char(Table);
              Gen(Col+1, Row1, Row5);
            end;
        Row1 := Row5+1;
        Row5 := Row1;
      end;
  end;                                              { Gen  internal proc}
begin                                                 { main Gen_table }
  Table := Ø;
  Gen(1, 1, Wrd_count);          { start in Colm 1, Row 1 thru Wrd_count }
end;

begin                        {   M A I N   }
  Initialize;                              { set up tables and other items }
  Read_words;                          { read in the file of search words }
  Sort_words;                              { convert and sort the words }
  Gen_tables;                    { generate the state table for the search }
  Read_text;                { read in the text file and perform the search }
end.
```

Listing 1. *(Continued from page 47.)*



used to represent the state diagram. The table uses 64 bytes to represent each state; a maximum of 250 states are allowed.

By converting the state diagram in Figure 1 to a table, we get Figure 2. Each state, shown as a circled number in Figure 1, occupies a *row* in Figure 2. The state numbers are the same as the row numbers of the state table. The column heading represents an incoming character from a text file. Finally, the value in a cell is a pointer to the next valid state (row) or is a code indicating success or failure.

To use the table, always begin in row 0 with the first character of the word. For example, assume DOGb is in the text file. The first character is D. The cell at row 0, column D contains 4 as its value. This means the state changes from 0 to 4. In row 4, column 0, O moves the pointer to row 5. Continuing, G moves the pointer to row 6 and b moves it to code H, which means Hit. The line is then displayed.

The empty cells in the table actually contain a code (254) that indicates a no-match condition. When this code is encountered, a scan-until-blank loop moves a pointer to the start of the next word. Suppose the first character of the next word is T. The cell for row 0, column T, is empty because none of the words in the list start with T. The high-speed scan causes the remaining characters of this word to be ignored; the scan then readies itself for processing of the next word by the state machine. By tracing through with various words, one can see that the diagram in Figure 1 is equivalent to the table in Figure 2.

XLAT

The 8086 instruction *XLAT* (translate AL) furnishes a fast way to implement state changes. *XLAT* requires that the DS:BX registers point to the row of the table appropriate to the current state. The AL register must contain the next character. *XLAT* translates AL to the contents of the cell according to the contents of the row.

For example, set DS:BX to point to row 0 and let AL contain the code for D. After executing *XLAT,* AL is translated from D to the value 4, changing the state

State diagram for CAR, CAT?, DOG, and DUCK

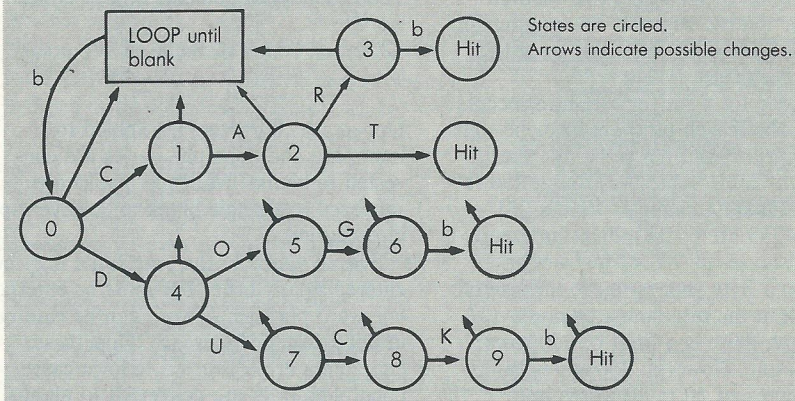


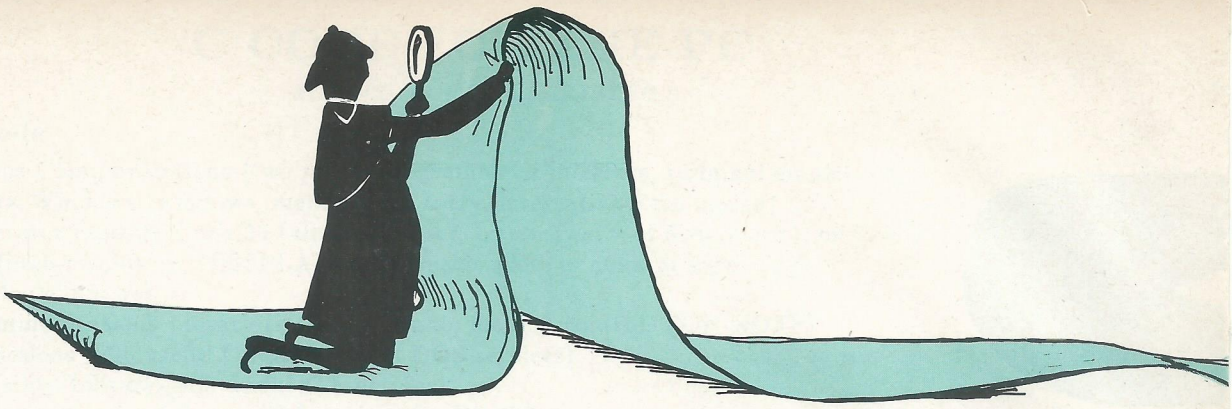
Figure 1.

State table

	Next Character read in															
	b	A	B	C	D	E	F	G	...	O	...	R	S	T	U	...
0				1	4											
1		2														
2												3		H		
3	H															
4										5					7	
5								6								
6	H															
7				8												
... 250																

Rows are states, columns are characters. Arrow shows state transitions for "DOGb."

Figure 2.



to 4. Because each row in the table is 64 bytes wide, the value 4 in the AL register is multiplied by 64 to get the updated value for the BX register. The pointer for state 4 is 256 bytes (4 × 64) from the base of the table.

If a code for a hit (or a failure) occurs instead, the search program branches out to appropriate routines to handle the condition. Table values 0 through 250 refer to valid state changes. Values 251 through 255 are codes indicating exceptions. Because the *XLAT* instruction works on a byte (not 16 bits), the size of each cell in the table must be one byte. Therefore, there is a limit of 250 rows for the table. However, 250 states can easily represent 50 to 80 words in a search list, enough for most uses.

How to use LFIND

By keying LFIND at the DOS command line, the program will display a prompt for the file names of a file containing the search-word list and the name of a text file. Or, one or both of these names can be entered from the command line. For example:

```
>lfind words.txt textfile.txt
```

means use the words found in WORDS.TXT and search the contents of TEXTFILE.TXT for any occurrences.

When a line in TEXTFILE.TXT is found that contains one or more words from the word list in WORDS.TXT, the line is displayed along with its line number. As an example, if "contains" is a search word and the text file contains this paragraph, the display would show:

```
1234:found that contains one or more
words
1236:ber. As an example, if "contains"
is a
```

Uppercase characters are folded to lowercase and nonalphamerics are converted to blanks. Multiple blanks are squeezed to a single blank to achieve rapid execution.

Search words in the search file may be entered in any order but must be entered one word per line. A word can be entered in uppercase or lowercase. Uppercase characters are converted to lowercase; nonalphamerics are converted to blanks. If more than one word appears on a line, only the first is used. For example, the file:

```
Cat?
dogs&frogs
don't
(128K or more)
The first word is accepted.
```

would be interpreted as:

```
cat?
dogs
don
128k
the
```

The program would search for only these words. (Normally, you would enter only one word per line.)

The text file can be any file containing ASCII characters. The only limitation is that each line must end with a CR character (hex 0D). A line from the text file is converted to lowercase and nonalphameric characters removed.

A word is defined as a sequence of alphameric characters enclosed in blanks. If DOG is a search word, we would get a hit on " dog " or " Dog " but not on "dogs" or "doggerel" (the leading and trailing blanks are important). If you want both DOG and DOGS, both must be in the search list. Alternatively, the ? wildcard character (as in DOG?) will yield a hit on any character string that has dog as the first three characters. Since about 80 words can be included in a search file, you have flexibility and control over the search pattern.

Generating the state table

The state table shown in Figure 2 is the key to the rapid execution of the search algorithm. The table is generated by converting to lowercase and then sorting the contents of the search file. Any duplicate words in the sorted list are removed to avoid wasting state-table entries. Duplicates would not slow the search process but would consume some of the allowed maximum of 250 table rows.

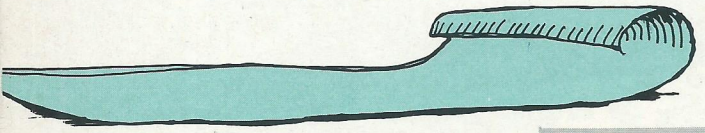
The table is generated from the sorted word list by the Pascal procedure *Gen_tables*. The sorted list is converted starting at the upper left-hand position as shown in Figure 3, where a period (.) means that this state is already represented in the table. Row 0 contains entries for c and d. The entry for c is a pointer to row 1, which represents either the a in car or cat?. The entry for d points to row 4, as shown in Figure 2.

The algorithm expressed in *Gen_tables* is presented here for the first time. It accepts as input a sorted word list and generates a state table. The internal procedure *Gen* looks down the sorted list (shown in the second column of Figure 3) until it comes to a character different from the one above it. Then it calls itself recursively, specifying the column and row(s) that, at the current level, contain the same letter. The recursive calls eventually encounter the end of a word, whereupon the procedure ends and control returns to the caller. Each encounter

Sorted word list

Search file	Sorted and folded	Processed by Gen
Dog	car	car
car	cat?	..t?
duck	dog	dog
CAT?	duck	.uck

Figure 3.



with a new (different) letter in a column adds a row to the state table.

In effect, a tree structure is traversed, wherein words that begin with the same sequence of letters are treated as sprouting from a common branch. This procedure illustrates the power of recursive processing. Without it, it would be very difficult to duplicate the action of this procedure. A much larger routine would have to be written.

X_str assembler procedure

The *X_str* procedure is called from Pascal to convert text characters to an internal code. *X_str* is called prior to sorting the word list. The search file and the text file must be converted using the same translation table the search uses so the search will be valid. Conversion moves the representation of characters to values below 64. The state table has rows that are 64 bytes wide and a translated value that is in fact an index into these rows, as discussed previously. Thus, the translation not only folds uppercase to lowercase, it also gets rid of all non-alphameric characters and at the same time moves the representation of these characters to a range below 64.

All three actions are accomplished with *XLAT*. Every character in the text file must be translated and this method is far more efficient than a complex arrangement of *IF-THEN-ELSE* statements.

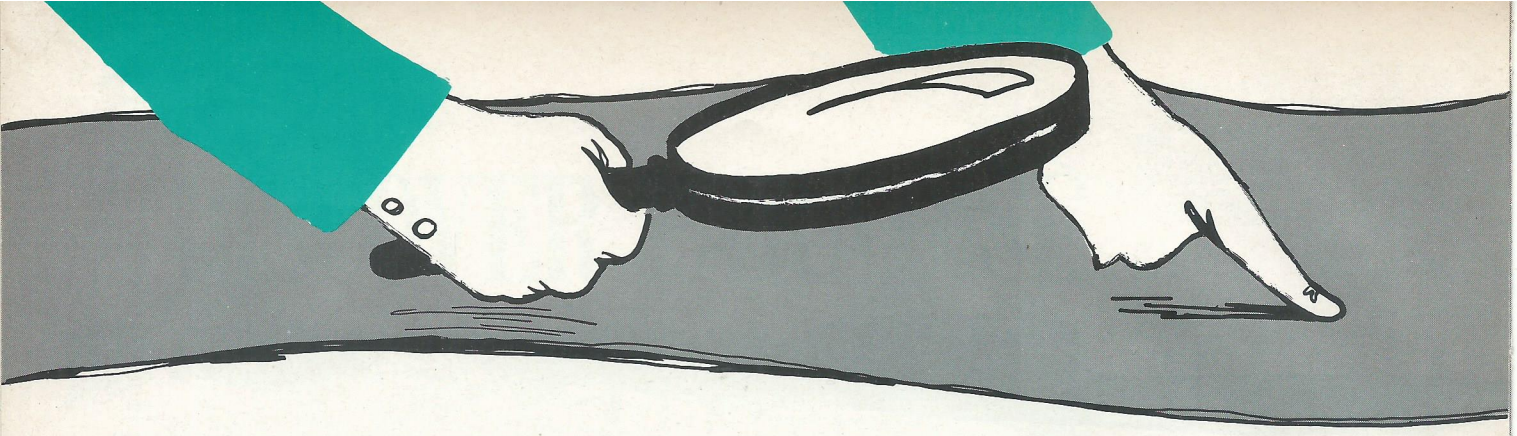
The translation table is created by the Pascal procedure *Initialize* and is stored in the *X_table* array. The *XLAT* instruction is used by the *X_str* procedure to perform the conversion. The 256 possible characters are converted to bytes ranging in value from 0 to 37. For example, the blank character is translated to 0 and the ASCII digits 0 to 9 are translated to the numbers 2 through 11.

Get_line and search

The *Get_line* and *Search* procedures shown in Listing 2 are written in assembler language for fast performance and to take advantage of specially useful 8086 machine instructions. The Pascal program reads a 12K block of bytes from the text file into a buffer and passes control to *Get_line*. *Get_line* translates one line of text at a time and saves it in a

```
; ------------------  SEARCH.ASM  -------------------------

;   The following constants are the same as in the Pascal code:
bl_end    equ   251 ; { code: means this is blank and successful search }
bl_next   equ   252 ; { code: means if blank char is next, then Ok, match }
any_next  equ   253 ; { code: means any char next is Ok, i.e., match found }
no_match  equ   254 ; { code: means no match found }
cr_code   equ   255 ;  used to indicate a carriage return code

GET_LINE        PROC NEAR
init_si :                       ; begin translation
        mov     si,[bp+24]      ; DS:SI points to Buffer contents
next:   mov     al,[si]         ; get a character from the Buffer
        cmp     al,26           ; Ctrl-Z encountered ?
        jne     no_z
; process EOF
        jmp     done            ; go home
no_z:   cmp     al,cr           ; is this a Cr character?
        jne     no_cr
;process Cr encountered in the input buffer
        cmp     ah,blnk_sp      ; is the last char a blank?
        je      bl_ok                   ; no, don't insert one, else:
        mov     byte ptr [di],blnk_sp  ;  need blank at the end string
        inc     di
bl_ok:  mov     word ptr [di],crlf      ; need this for displayed output
        inc     di
        inc     di
        mov     byte ptr [di],'$'       ;  '$' is end-of-string for DOS
        CALL    SEARCH          ; is there 'hit' in the string?
        jmp     again
no_cr:    ; process the character in AL
        xlat                    ; translate per X_table at DS:BX
        cmp     al,blnk_sp      ; is it a "blank" after translation?
        jne     no_blank        ; no, move it into T_word area
        cmp     ah,al           ; do we have 2 blanks in a row?
        je      again           ; if yes, don't put it in the string
no_blank:
        mov     ah,al           ; previous char = current char
        mov     [di],al         ; put translated character into T_word
        inc     di              ; place for next char
        cmp     di,dx           ; only enough room for 250 chrs
        jge     done            ; pretend end of line if too many
again:  inc     si              ; get next character in the Buffer
        loop    next            ; while not end of buffer
; buffer has been fully processed
        mov     si,[bp+8]       ; last DI address
        mov     [si],di         ;  must be saved for next time
done:   pop     es
        pop     ds
        pop     bp
        ret     24              ; 24  =  6 vars  *  4 bytes per var
GET_LINE        ENDP

SEARCH  PROC    NEAR
; determine if one of the search words is in the string
        mov     di,[bp+20]      ; set DI to start of the string
        inc     word ptr [di]   ; Line_counter++
        push    bx              ; save what we use
        push    cx
        push    dx
        push    di
; initialize for a dance through the state table
        mov     bx,[bp+16]      ; DS:BX points to S_table's first byte
        mov     dx,bx           ; BX saved in DX, BX reset for each word
        add     di,6            ; DI points one byte to left of string start
```

Listing 2. *(Continued on page 52.)*



```
get_char: ; get the coded next char from the next byte pos in the string
        inc     di              ; next byte
        mov     al,[di]         ; AL has it
        cmp     al,cr_code      ; is this end-of-string?
        jne     skip1           ;  no, continue
        jmp     no_hit          ;  yes, exit string search
skip1:  XLAT                    ; AL = translation per DS:BX[al]
        cmp     al,no_match     ; match failed for this word?
        je      eat_chars       ;  yes, eat nonblank chars
        cmp     al,any_next     ; any char next Ok, thus success
        je      success         ;  yes, display the string
        cmp     al,bl_next      ; blank-next state?
        je      blank_next      ;  yes, test the next char
        cmp     al,bl_end       ; blank and success?
        je      success         ;  yes, display the string
next_state: ; BX = (64 * AL) + DX :   move XLAT pointer to next state
        xor     ah,ah           ; zero out AH
        mov     cx,6            ; 2**6 = 64
        shl     ax,cl           ; AX = AX * 64
        mov     bx,dx           ; BX points to base of table
        add     bx,ax           ; BX points to base[64*AL]
        jmp     get_char        ; keep lookin'
eat_chars:  ; failure in the middle of a word, advance DI to next blank
        inc     di              ; eat nonblank
        cld                     ; look to the right for 'blank'
        mov     cx,250          ; max length of string$
        xor     al,al           ; scan for 00h = 'blank' char
        REPNE   SCASB           ;  starting at ES:DI
        mov     bx,dx           ; found it: reset for a new try
        dec     di
        jmp     get_char
blank_next:  ; if a blank is next: success; else eat chars
        inc     di
        mov     al,[di]
        cmp     al,0            ; 00h is the code for blank char
        jne     eat_chars       ; failed, eat nonblanks, try again
success:     ; convert to ASCII and display the string$
        les     di,[bp+20]      ; set ES:DI to start of T_word
        mov     ax,[di]         ; insigned integer value, line count
        xor     dx,dx           ; set up for 32-bit divide
        mov     cx,100          ; (DX:AX) / 100
        div     cx              ; quotient in DX,  rem in AX
        aam                     ; magic: AX  ==> BCD
        add     ax,3030h        ;        BCD ==> ASCII chars
        xchg    al,ah           ; reversed, per Intel way
        mov     [di+2],ax       ; lower two ASCII chars into the string
        mov     ax,dx           ; process the higher order digits
        aam
        xchg    al,ah
        add     ax,3030h
        mov     [di+4],ax
; remove leading 0's, e.g., 0031 ==> bb31
        mov     dx,di           ; use DX as end value
        mov     cx,di           ; save for later
        add     dx,4            ; last '0' is 4 bytes over
        add     di,2            ; [DI] is first '0'
zeros:  cmp     byte ptr [di],'0'
        jne     do_out          ; most significant digit
        mov     byte ptr [di],' '     ; replace '0'  with blank
        inc     di
        cmp     di,dx           ; third digit
        jbe     zeros
; convert code back to ASCII chars for display
do_out  ...
        ret
SEARCH  ENDP
```

Listing 2. *(Continued from page 51.)*

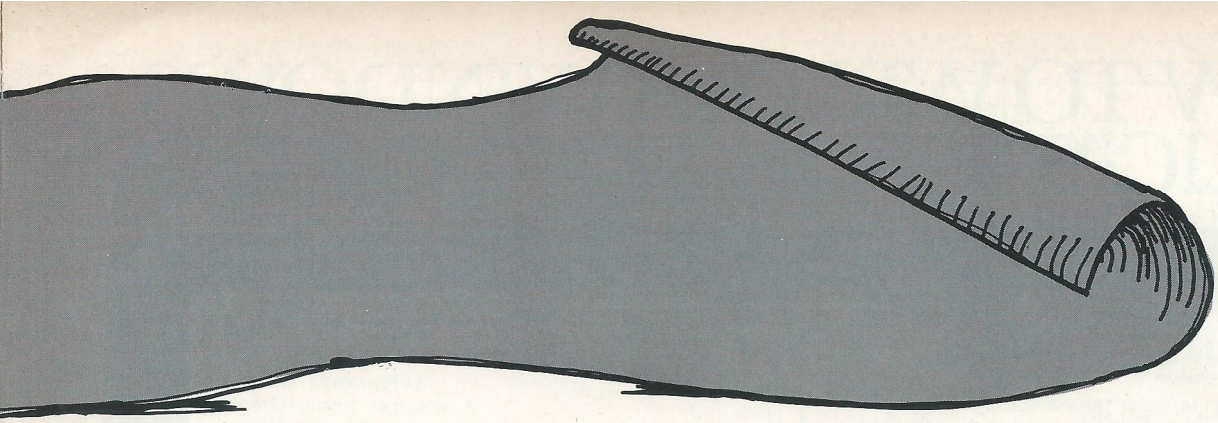
temporary buffer T_word. The line is compressed by converting all nonalphameric characters to blanks and compressing multiple blanks to one blank.

A line is defined as a sequence of bytes in the input buffer terminated by the 013 (carriage return) or 026 (EOF) characters. The translated line in T_word is then terminated with a special end-of-line byte (255) followed by a line feed and a $ character. Now it is ready to be processed by *Search* for an occurrence of a word in the list.

The strategy is first to convert an entire line and then scan it for search words. It would be possible to convert and scan at the same time, but this is not done here. The 8086 has too few registers to save the necessary pointers to the translate table, state table, input buffer, and line buffer. It is faster to set up the registers to translate a complete line of text, reset the registers, and do the scan. In addition, the search algorithm has fewer machine instructions when it works on a line that does not have multiple blanks. If a hit occurs anywhere on the line, the line is ready to be displayed without having to convert to an end-of-line. In short, it is less complicated and faster to convert a line, search a line, then unconvert and display a line if a word match occurs.

Using the state table, the *XLAT* instruction converts a translated text-file character to a value representing the next state or to a fail/success code. The state number is the next appropriate row number in the table. Since each row is 64 bytes wide, the state number is multiplied by 64 to get the offset to the next row. A shift left by six bit positions is used rather than *MUL* because shifting is much faster. Twenty machine instructions are executed per text character to walk through the state table. Only two memory accesses are performed: reading in the character and doing the *XLAT*.

If a success code is detected, the line is displayed. But more commonly a failure is detected in mid-word, so a scan-until-blank loop is executed. A *REPNE SCASB* instruction (repeat scan string, byte) is used to hunt for the next blank. In fact, most CPU time is spent in this eat_chars section of the search procedure. When *REPNE SCASB* was re-



Artwork: Dwight Been

coded to a *MOV, CMP, INC* and *LOOP* sequence, overall search times went up by a factor of almost three!

Displaying a line of text

The line number is stored in T_word as a binary integer and displayed as an ASCII character string. Conveniently, the AAM (ASCII adjust for multiply) instruction translates a hex integer in AX to a binary coded decimal (BCD) representation. The value in AX must be in the range 0 through 99 for this trick to work. Adding 3030h to AX converts BCD to ASCII decimal format. A loop replaces leading zeros with blanks.

The text buffer T_word reserves the first seven bytes of the string for the line number. The first two bytes hold a binary value representing the line number. This integer is incremented every time a string is encountered. The next four bytes are placeholders for an ASCII decimal representation of this line number. The seventh byte is :. A string looks like this:

```
<04D2h>1234:this is the line of text ... CrLf$
```

where <04D2h> is the two-byte binary line number.

As already discussed, text is internally represented as a code ranging from 0 through 37. The text is converted back to a string of ASCII characters and the 255 end-of-string byte converted to a carriage return character. After conversion the string is ready for display. DOS function 09 is used to display the text string. This function requires that the string terminate in $. The dollar sign was put there when the line was converted and compressed.

An advantage of using DOS function 09 is that output can be redirected. For example:

```
>lfind words textfile.txt > save.hit
```

directs the output to a file called SAVE.HIT.

Enlarging the search character-set

The values 39 through 63 are available to extend the character set beyond the alphamerics. You may wish to add the underscore character (_) to the list of characters looked at. Uppercase characters are folded to lowercase. Case identity can easily be preserved by modifying the translation table to include the 26 uppercase characters. However, LFIND then would become case-sensitive: "The" would be different from "the."

Remember, the search algorithm requires that a word be preceded by a blank character. So be careful about adding punctuation characters that might precede a word. If, for example, you added double quotes to the list of characters, the string "CAR" would be missed if only CAR was in the search list. You would also have to have "CAR" (with the quote character) in the search file. Avoid adding characters that often precede words.

The digits 0 through 9 (ASCII values 48 through 57) are converted to the values 2 through 11. The value 1 is assigned to the wildcard character ? and must not be reassigned. The alpha characters a through z and A through Z are translated to the values 12 through 37. All other characters are converted to 0, the code for blank. The values 38 through 63 are available to extend the search character set.

If you extend the character set, be sure to modify the *do—out* section of the assembler code. These instructions convert the 0 through 37 byte range back to ASCII characters for display.

Performance testing was done using the Pascal source file shown in Listing 1 and a 225K file containing 5,300 lines of text. A file of 80 nonsense words averaging five characters each was used to represent a worst-case situation (worst case because every line has to be completely scanned). A nonsense word also was used with LFIND, DOS FIND and WordPerfect to cause complete scanning.

The Turbo Pascal compiler is very fast, so it's included in the comparison. Of course, a code-producing compiler does more than merely scan, but it provides a comparison for those acquainted with its speed. The timings in Table 1 were run on an IBM XT.

The timings show that LFIND is about two-thirds as fast as DOS FIND. When the 80-word example is run, LFIND is more than 40 times faster than running FIND 80 times. For one word, LFIND is 3.2 times faster than a Turbo compile. If you want to find two or more words, or if case sensitivity or line numbers are factors, LFIND is superior to the DOS FIND command.

Complete versions of the source code listings are available on COMPUTER LANGUAGE's *Bulletin Board Service and CompuServe forum.*

E.J. Smith is a consultant in the San Francisco, Calif., area. He has been a programmer for 16 years and has developed PC software since 1982. His interests are algorithms, C, and personal computers.

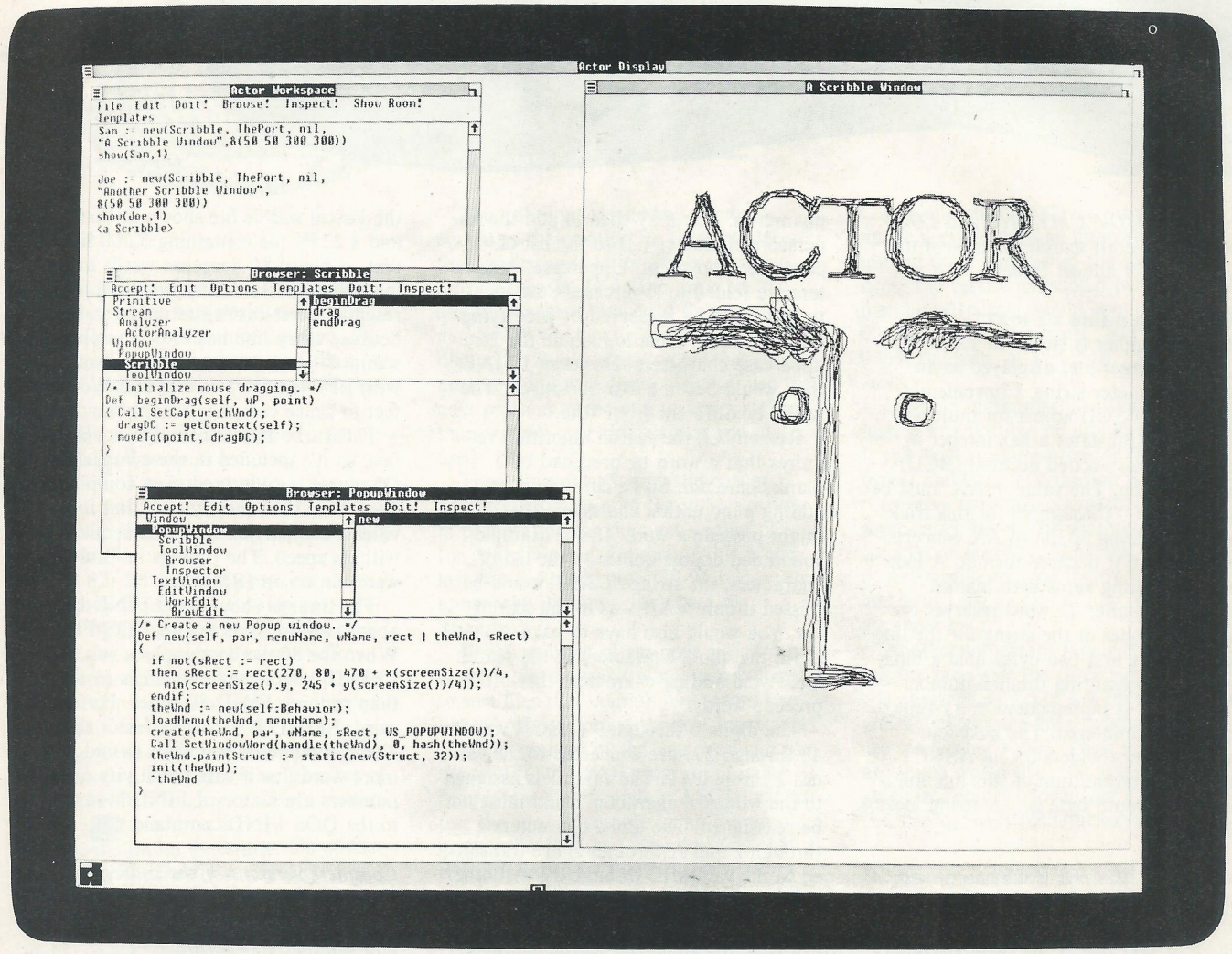
Timings

	LFIND.PAS	225K Text File
FIND, one word	0.9 sec	7.2 sec
LFIND, one word	1.2	12.5
LFIND, 80 words	1.2[1]	12.6[1]
Turbo compile	3.9	—
WordPerfect v. 4.2	4.1	93.9

[1] Not including about 1.0 sec needed to generate the state table from the 80-word search file.

Table 1.

HOW TO WRITE A WINDOWS APPLICATION IN TEN MINUTES.



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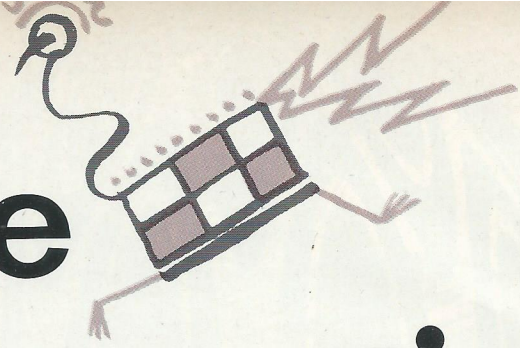


A Recipe for Self-Decorating Eggs

By Clifford A. Pickover

High on a green hilltop in Vegreville, Canada, stands a huge model of a Ukranian Easter egg. The surface of the egg monument is covered by what appear to be symmetrical designs of colored tiles, and the reflection of the gargantuan egg in the nearby lake enhances the monument's beauty.

Many of the ornaments of modern and ancient cultures consist of symmetrical and repeating designs. Consider the beautiful Moorish motifs in tiled floors and cloths. In this article, patterns reminiscent of ornaments with a repeating motif in at least two nonparallel directions are generated. The behavior of these patterns includes a network of periodic lines and patterns and visually random fluctuations.

The idea of investigating the decorations of various cultures by considering their symmetry groups appears to have originated long ago. From a purely artistic standpoint, some of the figures produced by this article's algorithm are reminiscent of Persian carpet designs, ceramic tile mosaics, Peruvian striped fabrics, and mosque brick patterns—in addition to Moorish ornamental patterns.

Today we continue to be fascinated with symmetry and repetition in design. For modern examples, consider the isometric designs of John Locke, the geometric ornaments of Russian artist Chernikow (where simple forms create complex interweavings), and a variety of popular art deco designs. Even nature often expresses itself in terms of repeating symmetries—cross sections of plants, phase transitions, standing waves on metal plates, muscle striations, snow crystals, and dendritic ice are just a few examples.

How can the beauty of the symmetrical ornaments and designs of various cultures be simulated with the aid of a computer? The computer is a machine which, when guided by an artist, can render images of captivating power and beauty, and mathematical equations provide a vast and deep reservoir from which the artist can draw.

New recipes, such as those outlined in this article, interact with such traditional elements as form, shading, and color to produce classical and futuristic images and effects. The mathematical recipes function as the artist's helper, quickly taking care of much of the repetitive and sometimes tedious detail. By becoming familiar with computer graphics, artists with access to computers will gradually change our perception of art.

The algorithm

The egg shapes generated for this article have been called chaos eggs by some ob-

```
Pseudocode for generating patterns on the egg's surface

To aid the reader in producing the plots in this article and to
encourage future studies into equations of the reader's own
design, the following algorithm is given.  Typical parameters for
the picture boundaries and various constants are also given.

ALGORITHM Egg Tile Generator

INPUT: Res, Betal, Beta2, Gamma, Alpha, Modf

TYPICAL PARAMETER VALUES:

Betal = -11, Beta2 = -12, Gamma = 60, Alpha = 10, Res = 500, Modf = 3
Betal = -16, Beta2 = -21, Gamma = 87, Alpha =  4, Res = 500, Modf = 2
Betal = -11, Beta2 = -12, Gamma =200, Alpha =  4, Res = 500, Modf = 3

OUTPUT:  Tile patterns composed of dots at positions (i,j)

do i = 1 to res;                        (* loop in x direction          *)
  do j = 1 to res;                      (* loop in y direction          *)
   x = Betal + (Gamma*i);               (* compute x                    *)
   y = Beta2 + (Gamma*j);               (* compute y                    *)
   z = Alpha*(sin (x) + sin (y));       (* compute z                    *)
   c = trunc (z);                       (* convert z to an integer      *)
   if mod(c,modf) = 0                   (* if c evenly divisible by modf *)
      then PlotDot(i,j);                (* plot a point at position (i,j)*)
  end;                                  (* End j loop                   *)
end;                                    (* End i loop                   *)
:efig.
```

Listing 1.

Figure 1.

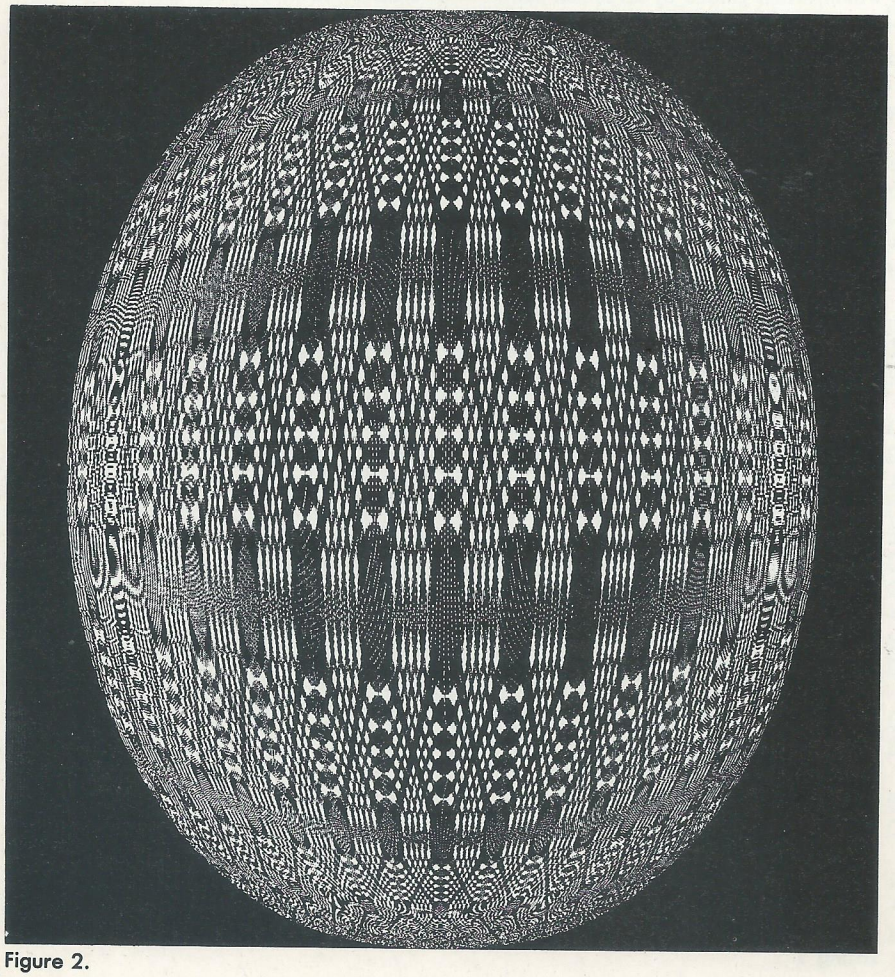
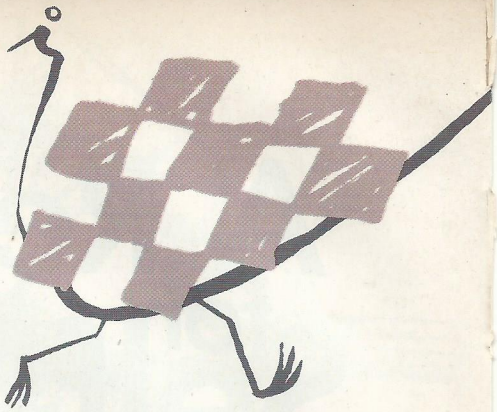


Figure 2.



servers because of their intricate designs and hard-to-predict behavior. These graphics experiments, with their variety of accompanying parameters, are good ways of characterizing the complexity of such behavior.

To compute the tiling patterns, a real number *z* is first calculated for a range of *(x,y)* pairs:

$$z_{xy} = \text{alpha } (\sin x + \sin y)$$

where alpha is a constant.

The resulting *z* value is truncated (made an integer) and divided by another integer, *m*. If the remainder is zero, a dot is plotted on the graphics screen at point *(x,y)* (Listing 1).

I first introduced this approach in "Blooming Integers" (see references). In the present article, a second transformation is applied to map this pattern to a sphere or ellipsoid. (Algorithms for spherical and other coordinate systems are not discussed here since they can be found in many computer graphics and mathematics texts. The references at the end of this article list many of these texts.)

Figures 1-3 are the resulting maps for a variety of values for alpha, *m*, and regions of *(x,y)* space. Aside from the fact that the maps are complex and aesthetically pleasing, several mathematical observations can be made.

For one, the alpha multiplier can be considered an entropy factor. As alpha increases, the disorder (entropy) of the egg increases until it looks almost random to the eye. For low values of alpha the pattern becomes perfectly ordered—somewhat crystalline in appearance. This phenomenon can be simply understood, in part, by noting that for smaller alpha the range of values for resultant *z* values is smaller, and therefore the pattern is obviously more repetitive, simple, and ordered.

Another simple observation is that as the mod factor, *m*, increases, the density of the system decreases. This too can be easily understood since fewer numbers are evenly divisible by 10 (for example) than by 3.

"No two are alike!" the saying goes when describing the intricate patterns found in snowflakes. Likewise, the few illustrations of chaos eggs here are a small set of the remarkable panoply of designs made possible with the algorithm. By turning the dial that controls *m* or alpha (or any of the other parameters in List-

designs is generated with relative computational simplicity. For this reason, the chaos eggs may be of interest to designers of museum exhibits and other educational displays for both children and adults.

Even in these simple equations, both stable and disorderly behavior can

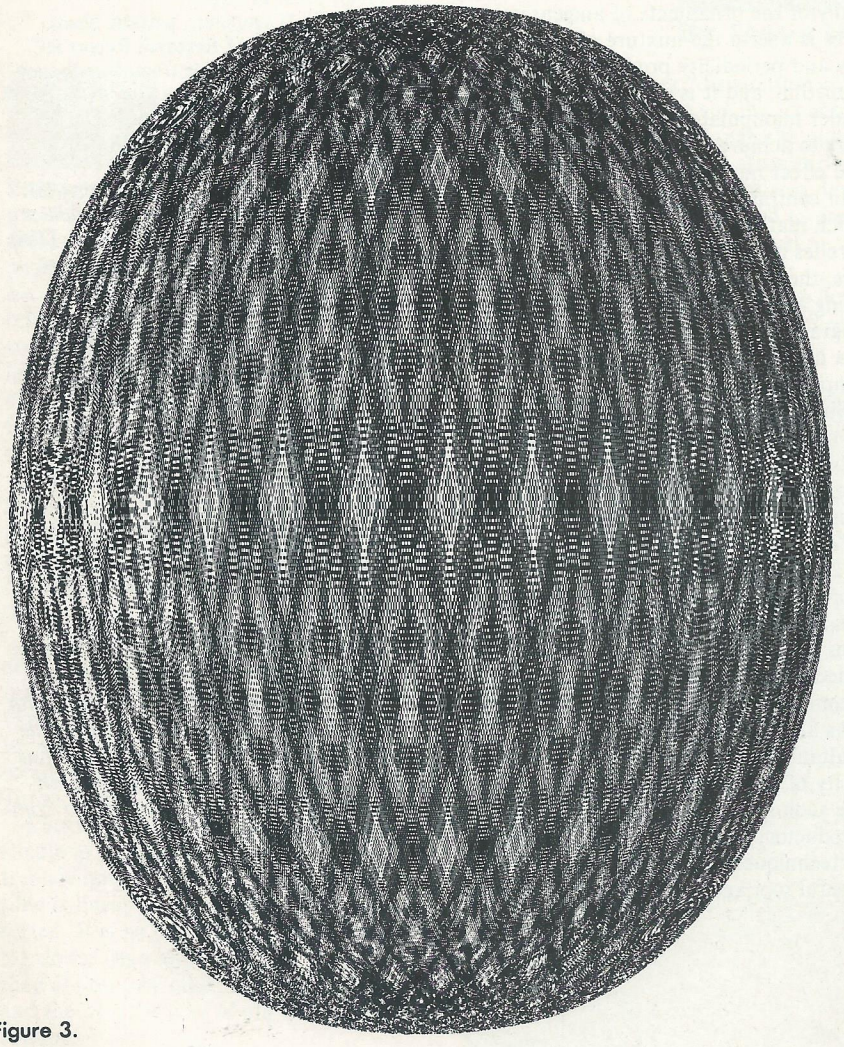


Figure 3.

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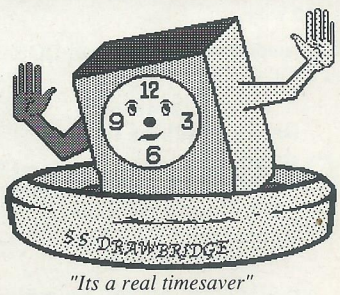

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emerge—the difference caused by a minute change in the input values. This behavior is qualitatively similar to that in chaos theory—the study of how complicated behavior can arise in systems based on simple rules and how minute changes in the input of a system can lead to large differences in the output.

The beauty and complexity of Figures 1-3 (and the many other shapes that can result from this algorithm) correspond to behavior no one could fully have appreciated or suspected before the age of the computer. This complexity makes it difficult to objectively characterize such structures. Therefore it is useful to develop graphics systems that allow the maps to be followed in a qualitative and quantitative way.

Though the equations seem to display what might be called bizarre behavior, there nevertheless seems to be a limited repertory of recurrent patterns.

The resemblance of the figures produced by the algorithm discussed here to many of the ornaments of ancient cultures is due to the mixture of stochasticity and periodicity produced by the algorithm, and it is suggested that the reader manipulate the various parameters to achieve artistic control of the visual effect most desired.

In contrast to previous systems in which mathematical and aesthetic beauty relies on the use of imaginary numbers, these calculations use real numbers. Doing so also facilitates their study with programming languages having no complex data types on small personal computers.

Since the original research in this article was done, an excellent article on a similar technique by Brian Hayes came to my attention ("On the bathtub algorithm for dot-matrix holograms," *COMPUTER LANGUAGE*, Mar. 1986, pp. 21-25). Hayes introduces the truncation approach as applied to the parabolic equation $z = x^2 + y^2$. His planar patterns are different than the figures presented here, and the reader is encouraged to compare the figures in both articles.

As already mentioned, the richness of resultant forms contrasts with the simplicity of the generating formula. An article such as this can only be viewed as introductory; however, it is hoped that the techniques and equations will provide a useful tool and stimulate future studies in the graphic characterization of the morphologically rich tiling patterns produced by such a simple generating formula.

I owe a special debt of gratitude to Alan Hauck (IBM) for familiarizing me with algorithms that map drawings to spherical surfaces.

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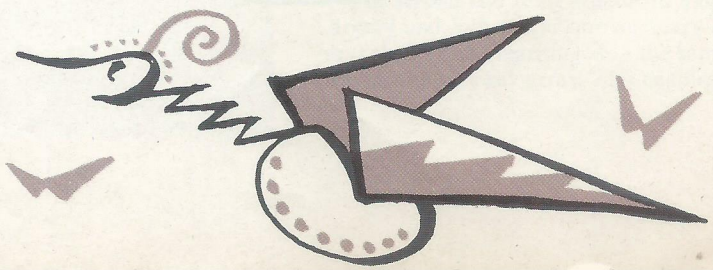
Clifford Pickover is a research staff member at the IBM Thomas J. Watson Research Center, Yorktown Heights, N.Y. He received his Ph.D. in molecular biophysics and biochemistry from Yale University, New Haven, Conn., and has since published numerous articles on novel graphical representations for complicated data.

Artwork: Steve Campbell



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Turbo Lightning	100	64
Turbo Lightning Word Wizard	70	47
Turbo Pascal and Tutor ... *New Version*	CALL	CALL
Turbo Pascal ... *New Version*	100	64
Turbo Pascal Tutor ... *New Version*	70	41
Turbo Pascal Database Toolbox ... *New Version*	100	64
Turbo Pascal Editor Toolbox ... *New Version*	100	64
Turbo Pascal Gameworks Toolbox ... *New Version*	100	64
Turbo Pascal Graphix Toolbox ... *New Version*	100	64
Turbo Pascal Numerical Methods Toolbox ... *New*	100	64
Turbo Prolog Compiler	100	64
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c compilers

C86PLUS *by Computer Innovations*	497	359
DeSmet C *w/Debugger & Large case*	209	184
DeSmet C *w/Debugger only*	159	138
Eco-C *Complete System by Ecosoft*	140	119
Instant C *by Rational Systems*	495	369
Instant-C/16M *by Rational Systems* ... *New*	895	695
Lattice C Compiler *vers. 3.2 from Lattice*	500	265
Mark Williams Let's C w/csd	75	54
Microsoft C Compiler w/CodeView ... *New Version*	450	269
Microsoft QuickC Compiler ... *New*	99	63
Optimum-C *by Datalight*	139	95
Turbo C Compiler *by Borland*	100	64
Uniware 68000/10/20 Cross Compiler *by SDS*	995	829

c interpreters

C-terp *by Gimpel, Specify compiler*	298	219
C Trainer *with Book by Catalytix*	122	87
Introducing C *by Computer Innovations*	125	99
Run/C *by Age of Reason*	120	69
Run/C Professional *by Age of Reason*	250	145

c utilities

Blackstar C Library *by Sterling Castle* ... *New*	125	98
C++ *by Guidelines w/version 1.1 kernel*	195	172
c-tree & r-tree Combo *by FairCom*	650	519
c-tree *ISAM File Manager*	395	315
r-tree *Report Generator*	295	239
Csharp Realtime Toolkit *by Systems Guild*	600	489
Curses Window Dev Pkg *by Aspen Scientific* ... *New*	119	105
with Source Code	289	249
dBx *dBASE to C Translator by Desktop AI*	350	299
with Source Code	550	419
Flash-up Windows *by Software Bottling*	90	78
GraphiC *Color version by Sci Endeavors*	350	274
GRAFLIB *by Sutrasoft*	175	159
HALO *Graphics by Media Cybernetics*	300	205
HALO Development Pkg *for Microsoft*	595	389
The HAMMER *by OES Systems*	195	129
PANEL *Forms Management by Roundhill*	295	215
PANEL/TC *for Turbo C by Roundhill*	129	95
PANEL Plus *by Roundhill*	495	395
PC Lint *by Gimpel Software*	139	99
PLOTHP *by Sutrasoft*	175	159
RTC PLUS *Fortran to C by Cobalt Blue*	450	399
Sapiens V8 *Virtual Memory Manager* ... *New*	300	265
Scientific Subroutine Library *by Peerless*	175	135
TE Text Editor *source by Sub Systems*	95	85
Vitamin C *by Creative Programming*	225	149
VC Screen *Forms Designer*	100	79
Zview *by Data Mgmt Consultants*	245	139

cobol language

COBOLspII *by Flexus*	395	329
FPLIB *for Realia COBOL by BCSoft*	149	129
Micro Focus COBOL *See Micro Focus Section*		
Microsoft COBOL *See Microsoft Section*		
PCDT *by Pro-Code*	995	895
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RM/COBOL *by Ryan-McFarland*	950	639
RM/COBOL 85 *by Ryan-McFarland*	1250	895
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RM/Screens ... *New*	395	334
SCREENIO *by Norcom*	400	379
screenplay *for COBOL by Flexus*	175	129

css products

Combo Package *by Custom Software Systems*	199	175
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PC/TOOLS *UNIX-like Utilities*	49	45
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debuggers & profilers

386 DEBUG *Cross Debugger by Phar Lap*	195	129
Advanced Trace-86 *by Morgan Computing*	175	115
Codesmith-86 *by Visual Age*	145	98
DSD87 *by Soft Advances*	125	79
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Periscope III *8 MHz version*	995	795
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The PROFILER *with Source Code by DWB*	125	89
TURBOsmith *Source debugger for Turbo Pascal*	99	89
The WATCHER *Profiler by Stony Brook*	60	51

disk utilities

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FASTBACK *by 5th Generation Systems*	179	129
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microsoft products

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c-tree *ISAM Mgr by FairCom*	395	315
dBx *with Library Source by Desktop AI*	550	419
DIRECTORY SHELL 286		
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Micro Focus Products *See Micro Focus Section*		
Microport Products *See Microport Section*		
Microsoft Products *See Microsoft Section*		
PANEL Plus *by Roundhill Computer Systems*	795	535
REAL-TOOLS *Binary Version by PCT*	99	89
Library Source Version	599	539
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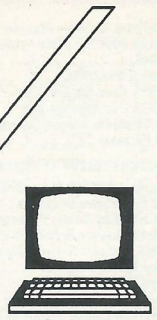

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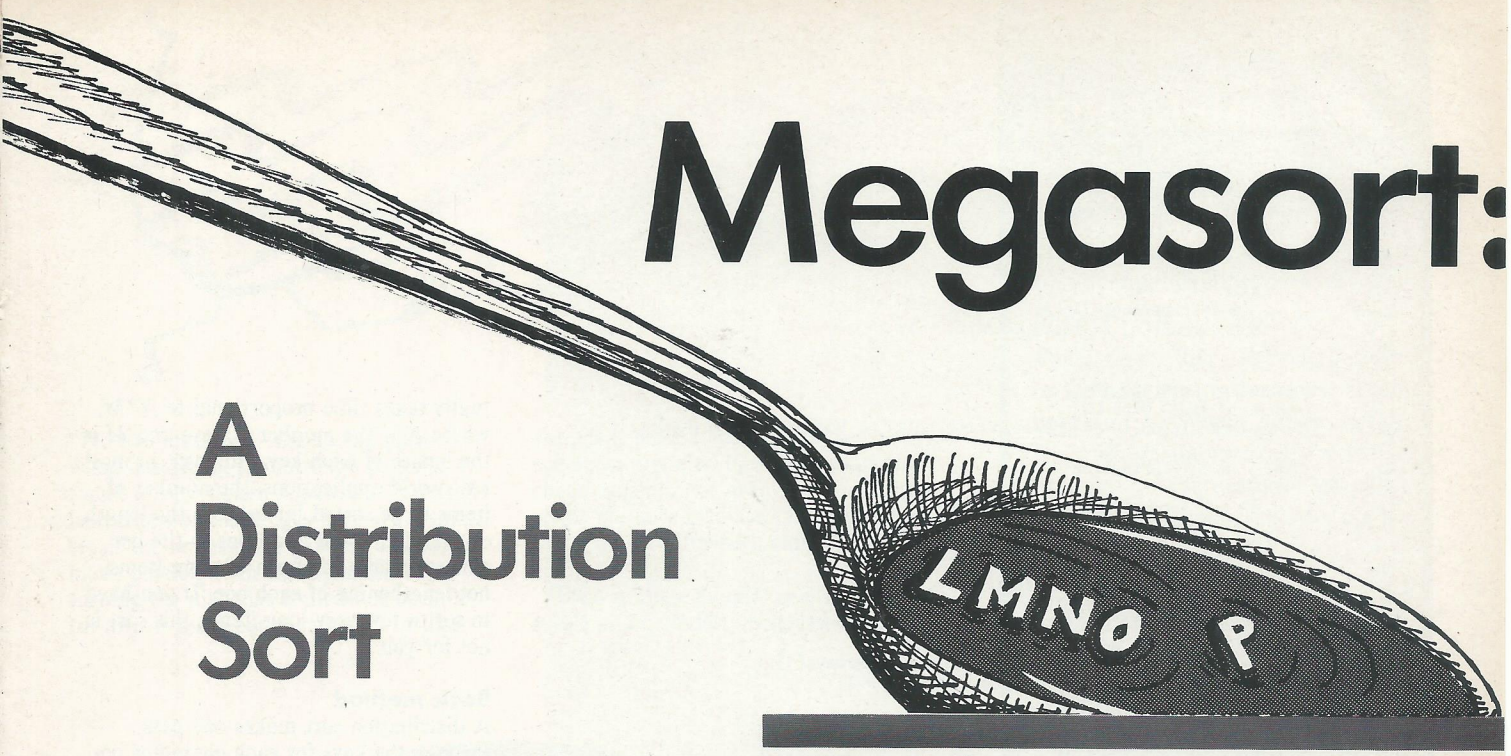
Megasort:

A Distribution Sort



By Steve Heller

A few months ago, while writing a fairly large Turbo Pascal program, I needed to sort a couple of lists of a few hundred to a few thousand keys of 10 characters into alphabetical order on an IBM PC compatible. My first impulse was to use the old reliable bubble sort. After all, how long could it take to sort such relatively short lists? Bubble sorts are extremely inefficient, and I certainly would not use one for a large sorting task, but this task didn't seem large to me.

For 1,000 keys, the processing took approximately 15 minutes—on a 7 MHz processor. Since I wanted to run the program repeatedly on slightly differing sets of data, I needed a considerably faster sort.

Of course, many sorting techniques are faster than the bubble sort; in fact, just about every other sort is faster. However, most of them are complicated to program, and I wanted something I could implement quickly and easily in Turbo Pascal.

Luckily, a sort does exist that is very simple to implement and still runs extremely quickly. In fact, its execution time is linear in the number of keys to be sorted. It is no more than a constant factor slower than any other sort, faster than almost any other on large arrays, and the simplest sort of all, in my opinion.

The sort I'm referring to is called a distribution sort and is described in Donald Knuth's *The Art of Computer Programming: Sorting and Searching*, Vol. 3, under the heading "distribution counting." It is one of three sorting techniques Knuth lists that are linear in the number of items to be sorted. The other two are radix exchange and radix list sort, both of which are more complicated to program, especially in a higher-level language.

As you can see in Listing 1, the actual code of the sort is only about 60 lines of Turbo Pascal. The time to do the sort depends both on the number of keys and the length of each key. The length of the keys is important because this program makes one pass over the input data for each character position of the keys to be sorted.

On each pass, the list is ordered by one more character position than on the previous pass. Therefore, this method ac-

```
 1: PROGRAM megaa; {Copyright 1986 by Steve Heller, Inc.  All rights reserved.}
 2:
 3: CONST
 4:   MaxSize = 5000;
 5:
 6: TYPE
 7:   AnyString = String[255];
 8:   SomeString = String[10];
 9:   StrPtrArr = ARRAY [1..MaxSize] OF ^AnyString;
10:   SortArray = ARRAY [Char] OF Integer;
11:
12: VAR
13:   TestArray : ^StrPtrArr;
14:   TestArray2 : ^StrPtrArr;
15:   TestArray3 : ^StrPtrArr;
16:   junk : AnyString;
17:   i : Integer;
18:   infile : text[10000];
19:   infilename : AnyString;
20:   outfile : text[10000];
21:   outfilename : AnyString;
22:   KeyLen : Integer;
23:   ArrayLength : Integer;
24:
25: PROCEDURE Megasort(VAR PtrArray:StrPtrArr; VAR SubArray1:StrPtrArr;
26:                    VAR Subarray2:StrPtrArr;
27:                    ArrayCount:Integer;KeyLength:Integer;ArraySize:Integer);
28:
29: VAR
30:   l : Char;
31:   m : Char;
32:   i : Integer;
33:   j : Integer;
34:   BucketCount  : SortArray;
35:   BucketPosition : SortArray;
36:   TempPtrArr : ^StrPtrArr;
37:   TempSubArr1: ^StrPtrArr;
38:   TempSubArr2: ^StrPtrArr;
39:
40:
```

Listing 1. *(Continued on page 64.)*

```
41: BEGIN
42:
43:   New(TempPtrArr);
44:   New(TempSubArr1);
45:   New(TempSubArr2);
46:
47:   FOR i := KeyLength DOWNTO 1 DO
48:     BEGIN
49:       FOR l := #0 TO #255 DO
50:         BucketCount[l] := 0;
51:       FOR j := 1 TO ArraySize DO
52:         BEGIN
53:           IF i > length(PtrArray[j]^) THEN
54:             m := #0
55:           ELSE
56:             m := PtrArray[j]^[i];
57:           BucketCount[m] := BucketCount[m] + 1;
58:         END;
59:
60:       BucketPosition[#0] := 1;
61:       FOR l := #1 TO #255 DO
62:         BucketPosition[l] := BucketCount[pred(l)] + BucketPosition[pred(l)];
63:
64:       FOR j := 1 TO ArraySize DO
65:         BEGIN
66:           IF i > length(PtrArray[j]^) THEN
67:             m := #0
68:           ELSE
69:             m := PtrArray[j]^[i];
70:           TempPtrArr^[BucketPosition[m]] := PtrArray[j];
71:           IF ArrayCount >=2 THEN
72:             TempSubArr1^[BucketPosition[m]] := SubArray1[j];
73:           IF ArrayCount =3 THEN
74:             TempSubArr2^[BucketPosition[m]] := SubArray2[j];
75:           BucketPosition[m] := BucketPosition[m] + 1;
76:         END;
77:
78:       FOR j := 1 TO ArraySize DO
79:         BEGIN
80:           PtrArray[j] := TempPtrArr^[j];
81:           IF ArrayCount >=2 THEN
82:             SubArray1[j] := TempSubArr1^[j];
83:           IF ArrayCount = 3 THEN
84:             SubArray2[j] := TempSubArr2^[j];
85:         END;
86:
87:     END;
88:
89:     Dispose(TempPtrArr);
90:     Dispose(TempSubArr1);
91:     Dispose(TempSubArr2);
92:
93:   END;
 98: BEGIN
 99:   New(TestArray);
100:
101:   Write('Input file name: ');
102:   ReadLn(infilename);
103:   Write('Output file name: ');
104:   ReadLn(outfilename);
105:   Write('Key length: ');
106:   ReadLn(KeyLen);
107:   Assign(infile,infilename);
108:   Reset(infile);
109:   Assign(outfile,outfilename);
110:   Rewrite(outfile);
111:
112:   WriteLn('Reading input file.');
113:
114:   i := 0;
115:   WHILE NOT EOF(infile) DO
116:     BEGIN
117:       i := i + 1;
118:       ReadLn(infile,junk);
119:       GetMem(TestArray^[i],length(junk)+1);
120:       TestArray^[i]^ := junk;
121:     END;
122:
123:   ArrayLength := i;
124:
125:   WriteLn('Sorting.');
126:
127:   Megasort(TestArray^,TestArray^,TestArray^,1,KeyLen,ArrayLength);
128:
129:   WriteLn('Writing output file.');
130:
131:   FOR i := 1 TO ArrayLength DO
132:     WriteLn(outfile,TestArray^[i]^);
133:
134:   Close(infile);
135:   Close(outfile);
136:
137:   WriteLn('Done.');
138:
139: END.
```

Listing 1. *(Continued from page 63.)*

tually takes time proportional to $N*M$, where N is the number of keys and M is the length of each key. However, in most real-world applications, the number of items to be sorted far exceeds the length of each item, and additions to the list generally take the form of more items, not lengthening of each one. If you have to sort a few very long items, this sort is not for you.

Basic method

A distribution sort makes one pass through the keys for each character position in the key to discover how many keys have each possible ASCII character in the character position we are currently considering. The sort then makes another pass to rearrange the keys.

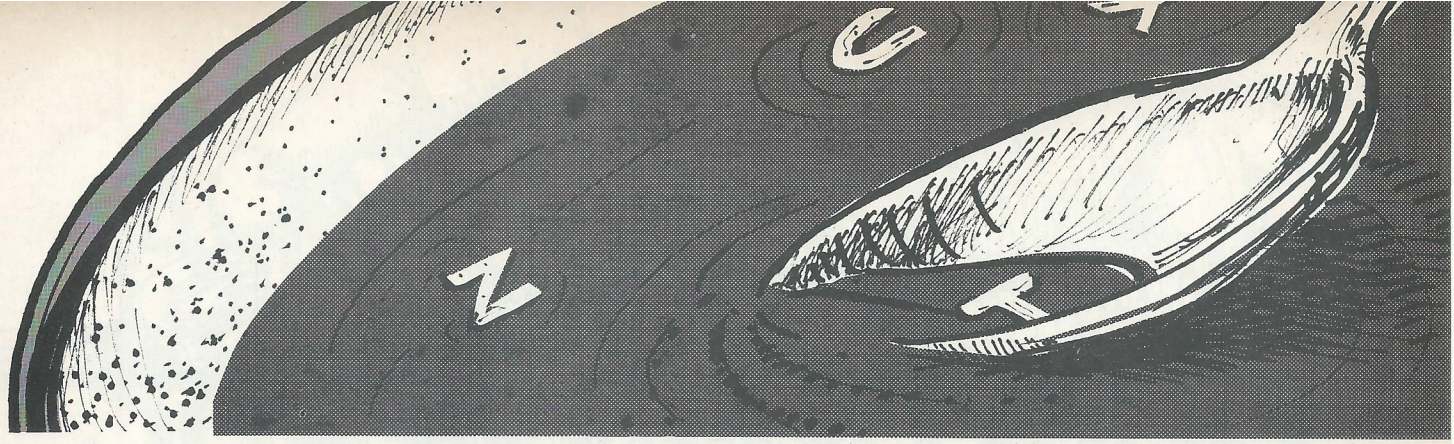
As a simplified example, suppose you have 10 keys to be sorted: three keys that begin with the letter A, five that begin with B, and two that begin with C—and you want to sort only on the first letter of each key. In this case, you can determine that the first key that starts with an A should be the first key in the result array, the second A key should be the second key, and the third A key should be the third key since all of the A keys should precede the B keys. The first key that starts with a B should be the fourth key, the second through fifth B keys should be the fifth through eighth keys, and the C keys should be numbers nine and 10 since all of the B keys should precede the C keys.

After describing the parameters and local variables needed for the *Megasort* procedure, I will go into more detail about the usual case in which the keys contain more than one character to be used in the sort.

Variables

As you can see from Listing 1, the *Megasort* procedure has six parameters. The first one, *PtrArray*, is the array of pointers to the sort keys. This array will be rearranged into ASCII character code order.

The second and third arguments, *SubArray1* and *SubArray2*, are auxiliary arrays that will be rearranged in the same way as the sort key array. This enables



you to keep several arrays in order by using one key.

For example, you might want to sort personnel records by last names of the employees. You would extract the last names and use them to form the sort key array. The auxiliary array would be pointers to the complete records. You would have to modify the procedure declaration to be able to use record arrays rather than string arrays for the auxiliary arrays. Of course, these first three parameters must be passed by address (*VAR* parameters) rather than by value so they can be modified during the sort.

The fourth parameter, *ArrayCount*, controls how many of the three possible arrays mentioned are actually processed during the sort. A value of 1 means only the key array will be processed, a value of 2 means the key array and one auxiliary array will be processed, and a value of 3 means the key array and both auxiliary arrays will be processed.

This parameter is necessary because Pascal does not allow procedures to take a variable number of arguments. If either or both of the auxiliary arrays will not be used, their argument positions in the call must be filled in with dummy array names of the same type, and the fourth parameter must be set to the appropriate value.

The fifth parameter, *KeyLength*, is the number of characters of each key that will be considered in the sort, starting from the left end of the key. This parameter enables you to limit the number of character positions to the number that is actually significant for your purposes. Any characters beyond this limit will be ignored in the sort, and any keys shorter than this limit will be padded on the right with nulls, ensuring that they will precede any longer keys that match them up to their ends in the final output.

The sixth parameter, *ArraySize*, is the number of keys to be sorted. *ArraySize* is necessary because Pascal requires the size of an actual array parameter to match the size of the formal array parameter. Therefore, you must use this parameter to limit the number of keys to be sorted to the number of valid entries in the key array.

In addition to the arguments, a number of local variables are required. The most important of these are *BucketCount* and *BucketPosition*, which are used in the calculation of the number of keys that fall in each distribution category, or bucket, and the three *Temp* arrays, which are used to hold the key pointers temporarily while they are being rearranged.

Megasort code

The code for the *Megasort* procedure begins at line 43 in Listing 1, calling the *New* procedure to allocate temporary arrays for use in the sorting process. The *i* loop that begins on line 47 counts backward from the last character of the key to the first, so that the sort proceeds from right to left. The right-to-left procedure ensures that two keys having the same key character in the current pass will maintain their order after the pass.

For example, if you are sorting the two keys ABC and ABD and are currently processing the second character position, the positions of ABC and ABD will not be exchanged. Therefore, if you sort from the right end first, after the first pass all the keys will be in order by last characters. After the second pass they will be in order by next-to-last and last characters, and so on.

The code to handle each character position in the keys starts at line 49. Lines 49-50 clear the sort array *BucketCount*, which keeps track of how many keys have each ASCII character code in the current position.

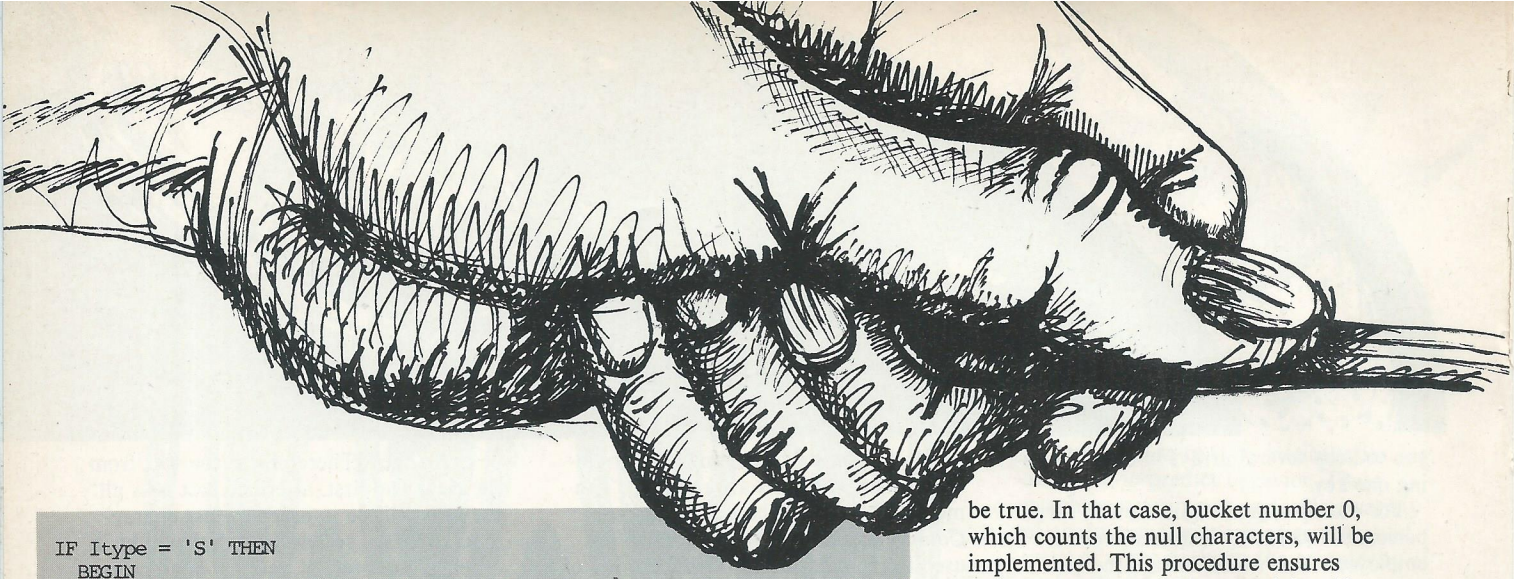
For example, *BucketCount['1']* keeps track of the number of keys that have the character 1, and *BucketCount['A']* does the same for the keys that have an A in the current sort position.

Lines 51-58 accumulate the key counts mentioned in the preceding paragraph. The *j* loop starting on line 51 steps through all the keys. The *IF* statement on lines 53-56 determines the bucket number that will be incremented to account for the key currently being processed. If the character position currently being processed is past the end of the current key, the expression on line 53 will

```
{SORTDAT.PAS - generates sort data for MEGASORT testing}
{861223 :2200}

VAR
  i,j : Integer;
  ir  : Real;
  s : String[255];
  t : Text[10000];
  n : Real;
  Itype : Char;
  MaxLength : Integer;
  Ran : Char;
  RealTemp : Real;
  IntTemp : Integer;
  RealExp : ARRAY [-30..30] OF Real;
  FName   : String[80];
BEGIN
  RealExp[-30] := 1E-30;
  FOR i := -29 TO 30 DO
    RealExp[i] := RealExp[i-1]*10;
  Write('Name of data file to be generated: ');
  ReadLn(FName);
  Write('Number of items to generate: ');
  ReadLn(n);
  Write('Type of items (R for real, I for integer, S for string): ');
  ReadLn(Itype);
  Itype := Upcase(Itype);
```

Listing 2. *(Continued on page 66.)*



```
IF Itype = 'S' THEN
  BEGIN
    Write('Maximum length of strings: ');
    ReadLn(MaxLength);
    Write('Random string length or all maximum length (R or M): ');
    ReadLn(Ran);
    Ran := Upcase(Ran);
  END;

Assign(t,Fname);
Rewrite(t);
ir := 1.Ø;
REPEAT
  BEGIN
    IF ir = 1ØØØ*int(ir/1ØØØ) THEN WriteLn(ir:1Ø:Ø);
    IF Itype = 'S' THEN
      BEGIN
        s := '';
        IF Ran = 'R' THEN
          FOR j := 1 TO random(MaxLength) DO
            s := s + chr(random(64)+32)
        ELSE
          FOR j := 1 TO MaxLength DO
            s := s + chr(random(64)+32);
        WriteLn(t,s);
          END
        ELSE IF Itype = 'R' THEN
          BEGIN
            RealTemp := Random;
            IF Random > Ø.5 THEN
              RealTemp := -RealTemp;
            IntTemp := Random(3Ø);
            RealTemp := RealTemp * RealExp[IntTemp];
            Str(RealTemp,s);
            IF RealTemp > Ø THEN
              s := copy(s,3,length(s))
            ELSE
              s := copy(s,2,length(s));
            WriteLn(t,s);
          END
        ELSE IF Itype = 'I' THEN
          BEGIN
            IntTemp := Random(32767);
            IF Random >Ø.5 THEN
              IntTemp := -IntTemp;
            Str(IntTemp,s);
            WriteLn(t,s);
          END;
      END;
      ir := ir + 1.Ø;
    UNTIL ir > n;
    Close(t);
  END.
```

Listing 2. *(Continued from page 65.)*

be true. In that case, bucket number 0, which counts the null characters, will be implemented. This procedure ensures that shorter keys will be sorted first if their first characters are the same as those of a longer key.

For instance, XYZABC will be sorted before XYZABCA if the *KeyLength* parameter is at least 7, because XYZABC is effectively padded on the right with at least one null character.

On the other hand, if the character position currently being processed is within the length of the key currently being processed, the assignment on line 56 will select the bucket to be incremented according to the ASCII value of the *i*th character of the *j*th key.

If you are processing the second character position and the current key is "The chip is fast," *BucketCount['h']* will be selected to be incremented. Line 57 increments the bucket selected by the *IF* statement.

After the *j* loop from lines 51-58 has been executed for each key in the key array, the buckets in *BucketCount* contain the counts for each possible character value in the keys (for the current character position).

However, you need the cumulative count of keys for each character value. That is, suppose you want to sort the following one-character keys:

C
B
A
D
B
D
C
A
B
D

Of the 10 keys, you have the following bucket distribution:

Bucket	A	B	C	D
Counts	2	3	2	3

But you really want to know where the As start, where the Bs start, etc. The table you want looks like this:

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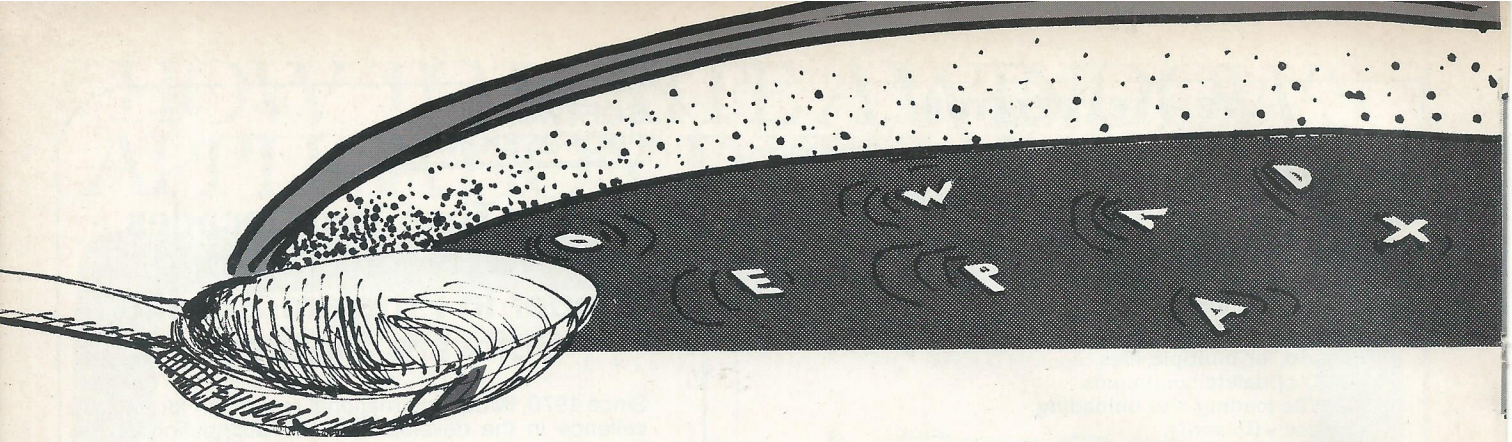

Bucket	A	B	C	D
Positions	1	3	6	8

Now you know that you should move the first A to the first position in the output, the first B to the third position, the first C to the sixth position, and the first D to the eighth position. How is this table derived?

The Bucket positions table is computed by the following procedure:

- (Line 60) The first output always goes to output position 1.
- (Line 61) For all the rest of the bucket positions, *do*.
- (Line 62) Each bucket position starts at the previous bucket position plus the number of items in the previous bucket.

Now you are ready to move the key pointers (and the auxiliary array pointers) to their respective places in the output of this sorting pass. The *j* loop starting on line 64 does this. First, on lines 66-69, it computes which bucket of the *BucketPosition* array should be used for the output addressing.

As in the initial determination of the *BucketCount* array (lines 51-58), if a key value's length is less than the character position you are currently processing, the key is assigned to bucket #0. Otherwise, the *BucketPosition* element is determined by the ASCII value of the character at the current position in the key.

Then, in line 70, the key pointer is copied to the position in *TempPtrArr* that corresponds to its *BucketPosition* entry. Lines 71-74 do the same for the auxiliary arrays that need to be sorted along with the key array. Line 75 increments the *BucketPosition* entry so the next key that uses that entry will use the next position in the output array rather than writing over the position you just used.

Then, lines 78-85 copy the output pointer arrays back to the main arrays, in preparation for the next sorting pass (or completion of the sort, if this is the last pass). Finally, lines 89-91 release the temporary storage arrays used by *Megasort*.

The remainder of the code in Listing 1 is the main program, which can be used to sort files that contain one record per line of ASCII data if the sort key starts at the beginning of the line. You can use the SORTDAT.PAS program (Listing 2) to create a file of random ASCII text to test the sort. If you are using the program from Listing 1, you will find that the time taken by the sort itself (from the "Sorting." message to "Writing output file.") will be only 42 seconds for 5,000 10-byte keys on a 4.77 MHz 8088 machine such as an IBM PC.

I have written an InLine-accelerated version of Megasort, which can do the same sort in only six seconds, as well as a C version and a 68000 assembly language version. Anyone interested in obtaining these versions of the sort, or in using the version presented here for commercial purposes, should contact me at Chrysalis Software Corp., P.O. Box 0335, Baldwin, N.Y. 11510, (516) 868-2698.

I am not claiming that Megasort is the fastest sort possible on any kind of data. If the keys are long (greater than 10 bytes) and their distribution is known, then other sorts are competitive, or in some cases faster (for example, address calculation sorting). However, Megasort is very simple to code in any language and is at least as fast as any other sort for short keys.

Another important factor in comparing the speeds of the three sorting methods analyzed in Table 1 is that Unshuffle and Quicksort are data-dependent (as are most other sorts). Their worst cases are much worse than the average cases given in Table 1. According to Knuth, the average case for Quicksort is:

$$10.63 * N * \ln(N) + 2.11 * N$$

or 10 seconds for $N = 100000$, assuming an instruction time of 1 microsecond. The worst case is given as:

$$>= N*N$$

or at least 2.78 hours, for the same N. Megasort does not have this drawback, as its timing is data-independent; the figures given are valid for all possible data sets.

The times given in Table 1 were provided by Bob Gebelein, who has coded all of the sorts in 68000 assembly language and calculated their timing from 68000 cycle counts. The key lengths specified at the top apply only to Megasort, as timings of the other sorts are relatively independent of key length. ■

Steve Heller is president of Chrysalis Software Corp., Baldwin, N.Y. He has been programming for the last 18 years, and graduated from Shimer College, Waukegan, Ill., in 1970.

Artwork: Mark Duran

Comparing the three sorts (sec)

Number of records	Unshuffle	Quicksort	Megasort k=2	Megasort k=3	Megasort k=4	Megasort k=5	Megasort k=10	Megasort k=15
500	.33	.15	.04	.05	.07	.10	.19	.28
1,000	.91	.34	.08	.10	.14	.18	.35	.52
5,000	10.17	2.16	.38	.53	.69	.86	1.64	2.43
10,000	29.06	4.68	.76	1.06	1.37	1.70	3.26	4.82
15,000	56.05	7.16	1.14	1.59	2.06	2.54	4.88	7.22
50,000	428.72	27.21	3.77	5.31	6.87	8.43	16.19	23.96

Key lengths 2, 3, and 4 were illustrated because they reflect some very common sort keys. Key length 2 is, of course, a 16-bit integer, which is commonly used as a record number. 3 represents a telephone number or a ZIP code, coded as a binary number, and 4 represents a Social Security number, coded as a binary number.

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PUBLIC DOMAIN SOFTWARE REVIEW

Pascal programming aids and PC-FASTYPE

By Tim Parker

For most programmers, the hardest part of coding is debugging. When this stage arrives, programmers turn to a number of utilities. A source listing formatter, variable cross-referencer, and syntax checker are becoming standard tools for all languages. They dramatically reduce debugging time and make it much less of an onerous task.

Useful utilities are available in the commercial market and the public domain. Almost every language has a good package available, usually written by a programmer who spends most of his or her development time in that language. Some programmers become dependent on these utilities since they are superb products and excellent productivity aids.

Although the public domain has always had formatters, variable cross-referencers, and other utilities, most have been simple, rudimentary programs. But with the development of improved compilers, debuggers became more powerful; and as the use of languages became more widespread, the demand for commercial products arose.

In the September column, I discussed a utility program called SNAP! for the dBASE family ("dBASE becomes a SNAP!; a C graphics library," *COMPUTER LANGUAGE,* Sept. 1987, pp. 77-79). SNAP! matched commercial products in every regard and exceeded most. I do virtually all of my code checking in dBASE with SNAP!, and I highly recommend it for any dBASE programmer.

Thanks to the evolution of low-cost, full-feature compilers, Pascal has really caught on over the last few years, resulting in a number of new tools for this language. From the early days of CP/M, when JRT Pascal became available for about $50, to the emergence of Borland International's Turbo Pascal, Pascal has become the most popular language to learn first, replacing BASIC for IBM PCs and similar machines. Borland International's compiler, now heading into its fourth edition, still costs under $100.

With the popularity of Turbo Pascal, a new market of commercial products written in the language has arisen. Most of these are extensions and utilities. The public domain has benefitted from the large number of Turbo Pascal users, too. I have reviewed many Turbo Pascal utilities, such as Boosters, a group of machine language functions that enhance the language ("Libraries for C—and one for Turbo Pascal," *COMPUTER LANGUAGE,* Feb. 1987, pp. 91-94).

However, despite casual mentions of programs encountered on SIG disks, I haven't focused on a good productivity aid like SNAP! for Turbo Pascal because I could never find one that was good enough. Oh, there were formatters and a few cross-referencers, but none of them could be called anything more than utilities.

T-Ref parses and produces formatted code and variable cross-referencing for compilable Turbo Pascal code

However, this situation has changed, and a useful program that will be of interest to all Turbo Pascal users has finally crossed my desk.

T-Ref is a combined source lister and cross-referencer in Pascal that deserves a look. T-Ref requires DOS 2.0 or later and a minimum of 256K RAM, although at least 512K RAM is highly recommended. T-Ref works with Turbo Pascal versions 2 and 3. The program parsed just about any Pascal code that didn't include too many deviations from Turbo Pascal's command set.

T-Ref imposes a few limitations on code and variable checking. The first 20 characters of a variable are used for identification and the rest are ignored. The maximum string length is 130 characters and the maximum column width 132 characters. Depth-level checking is a maximum of 20 levels.

In checking code, T-Ref has one major flaw I suspect will be corrected with a future enhancement: it doesn't recover well from errors. When T-Ref is run on source code containing errors, such as mismatched conditionals or unrecognized symbols, it finds the error and bombs out, producing a cross-reference list of variables to that point and closing the formatted file output, if either or both are requested. An error message is then displayed.

T-Ref does not claim to be a syntax checker. However, most programmers would probably prefer a package that scans code and generates a list of errors, enabling them to debug faster. Instead, T-Ref should be run only on code that will compile (the manual points this out). A proper syntax checker would greatly improve T-Ref's usefulness.

T-Ref parses and produces formatted code and variable cross-referencing for compilable Turbo Pascal code. The program handles valid declaration sections of source code, from constants to procedures and functions. This feature allows a library of procedures or functions to be parsed for future reference.

When executed, T-Ref presents a full screen display used as the main menu. The top part of the screen indicates the current active directory, input file, and output file. A number of option toggles are indicated below that in two areas of the screen. One area refers to source listing options, the other to cross-referencing. The bottom section of the screen contains messages and key prompts.

Pop-up menus are available with T-Ref. The F1 help function key produces a list of what the function keys do, while the F2 function key is context-sensitive, producing relevant help information depending on the cursor location. Other pop-up menus are used for system options (such as header information for the source listing), cross referencing, and other parameters. A configuration can be saved as the default type with a function key.

The source listing parameters control a number of options. Reserve words can be formatted into upper case or forced to lower case or into formal naming conventions. (Formal naming usually refers to capitalizing the first letter of the reserved word, with the subsequent letters in lower case.) Similar formatting of identifiers can also be controlled.

The source listing can have line numbers printed in the left margin. If files are *included*, the line numbering splits into two, with one column providing numbering for the entire file and the line number held constant while the *included* file is produced, and the second column providing numbering for the particular *included* file. When source code is listed and files are *included*, the source *includes* the full source code for that *included* file also. This option can be turned off to prevent parsing of *included* material.

An option called lexical level produces a listing with the depth of conditional or other tiered code indicated by a digit. Thus, a procedure is numbered as 1 when printed until it calls another procedure, then the number increases to show the level is now 2. As the levels are closed, the numbering decreases.

Block levels can be numbered in the same manner. When a *BEGIN, FOR,* or similar statement is encountered, the numbering increases; as *END* statements are encountered, the numbering decreases. An active procedure column on the right of the listing produces in brackets the name of the function, procedure, or program active at that point.

This numbering creates a fairly strange-looking listing, especially if all the numbering options are active. Therefore, line numbers can be in the left column, increasing steadily unless an *include* statement is encountered, where it holds the number steady and a second column appears that increases through the *included* code. If levels and blocks are active, two additional number columns appear. Finally, the active control code is presented on the right. These options are useful for debugging purposes (although T-Ref isn't designed for debugging since it crashes on bugs) and even better for documentation and determining logic flow.

If a header field is desired, it can be printed at the top of each source page. Headers have a maximum of five lines and can be up to 75 characters wide. Page numbering can also be toggled, with a date and time mark printed.

The cross-reference section produces a list of the variables in the code and information about the type of variables. All occurrences of a particular variable are noted.

The format of the cross-reference listing is different from most others. Next to the name of the variable, the basic type (label, constant, function, etc.) and the data type (integer, byte, Boolean, etc.) are noted. The declaration's line number appears on the next line (along with procedure name and number, if applicable) with the lexical level of the declaration within the overall program. If the declaration is not encountered within the examined code (for example, when a library that uses a global variable is parsed), a statement indicating this is printed. Each occurrence of the variable is then noted on subsequent lines with the line number.

Reserved words are identified by T-Ref. Reserved Turbo Pascal words for Turbo versions to 3.01 are included in the utility I tested and listed in an appendix of the manual. An asterisk indicates that the variable was explicitly set on the occurrence.

T-Ref checks procedures and functions for recursion and notes the results in the printout. Formal parameters explicitly set in the code are also noted in the

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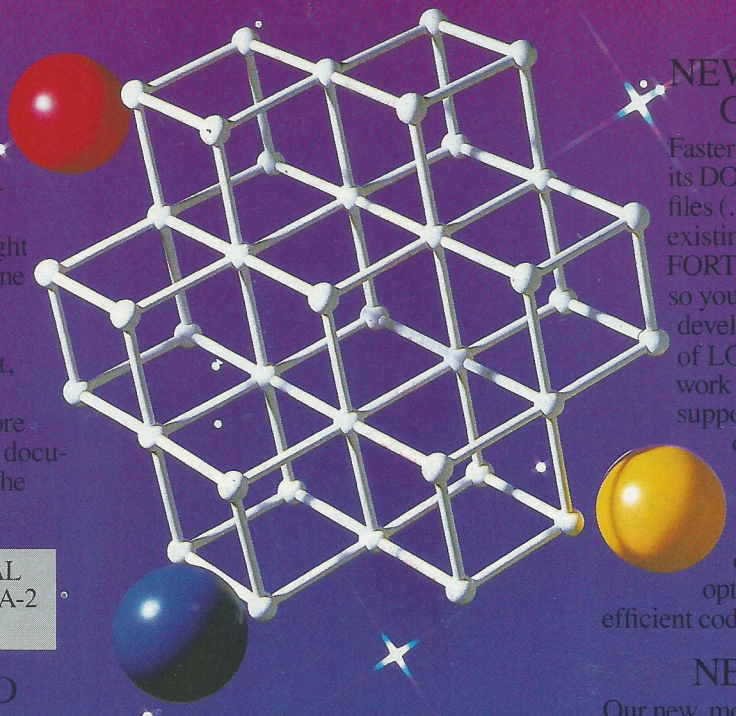

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printout and don't cause an error. (There are times when explicit assignment of formal parameters are useful.)

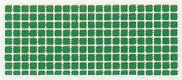
T-Ref also produces a procedure and function map, listing the procedures and functions that have been parsed and the declaration line number. The total number of lines parsed (identifier type by basic type and data type) and the total number of identifiers are given.

Headers and page formatting options similar to those I described for the source printout are available within the cross-reference section. These options are not necessarily the same as those of the formatter, giving the user some control over printing headers in the source but not in the variable cross-reference (or a similar arrangement).

The manual accompanying T-Ref is about 30 pages long and provides a good discussion of the program and its capabilities. The options are discussed and examples are given. A listing of error messages T-Ref generates is included in an appendix.

T-Ref performed exactly as it should have. I tested it with Roy MacLean's FICALCS, a program I discussed in the January issue ("Financial calculations and Batch files, *COMPUTER LANGUAGE*, Jan. 87, pp. 83-85). T-Ref handled FICALCS easily despite FICALC's size and complexity and produced useful source code printouts. I found the variable cross-reference a bit confusing to read, but I'm used to the simpler cross-reference listings that provide the variable name, type, and all occurrences in a few lines. The verbosity of T-Ref's printout could be useful, although cross-referencing after the fact is usually performed for modification and documentation only.

If a code syntax checker and subsequent error display were added to T-Ref, users would be able to cross check and format source as they develop code instead of when they complete it. However, for Turbo Pascal programmers, T-Ref is a useful utility and well worth acquiring. Although I worked with v. 1.01, v. 1.1 is now available with a number of additional functions. A donation of $35 is requested to become a registered user of T-Ref and receive the latest updates.



PC-FASTYPE is a shareware program designed specifically for IBM PCs and compatibles. The author requests a $20 donation if it is found useful. Two versions of the program are distributed: one for the older keyboards and one for the enhanced keyboards. PC-FASTYPE requires a CGA or similar (EGA, Compaq, etc.) card to work. It will not function on a Hercules card.

PC-FASTYPE performs several tasks, including presenting a series of drills to practice and tie the user's keyboard pounding. It also has lessons for touch-typing on IBM keyboards. (Those with modified, nonstandard keyboards or IBM-compatible keyboards may have to adjust.)

PC-FASTYPE makes extensive use of the function keys and has numerous menus. A highlight system is used for menu picks. The program is well presented, and a computer novice can easily use it. PC-FASTYPE is fast and easily handled my 85 words-per-minute test. It was originally written in BASICA but was converted and compiled with QuickBASIC.

PC-FASTYPE can be set for beginner, intermediate, and expert levels, and the difficulty of the lessons and tests accelerates as the level increases. When in testing mode, PC-FASTYPE presents a text box after you've typed that gives a number of interesting parameters, such as a true words-per-minute rate (considering errors), raw words-per-minute rate (ignoring errors), the number of keystrokes, etc.

The documentation comes in two files: one contains the manual and the other an update for the new version (I tested v. 3.0). The documentation is well written and clearly explains how to use the program.

In testing, PC-FASTYPE presented lessons, measured typing speed, and provided practice in pounding the keys. It locked up my machine a couple of times in early tests because of memory residents.

Not everyone needs a program like PC-FASTYPE, but for those who want to learn touch-typing, improve their typing skills, or determine their typing speed, it is well suited. The limitation of CGA or EGA is unfortunate, and a Hercules version would probably be popular.

Tim Parker is a systems programmer in Ontario, Canada, who also writes for several technical magazines.

Products mentioned

T-Ref
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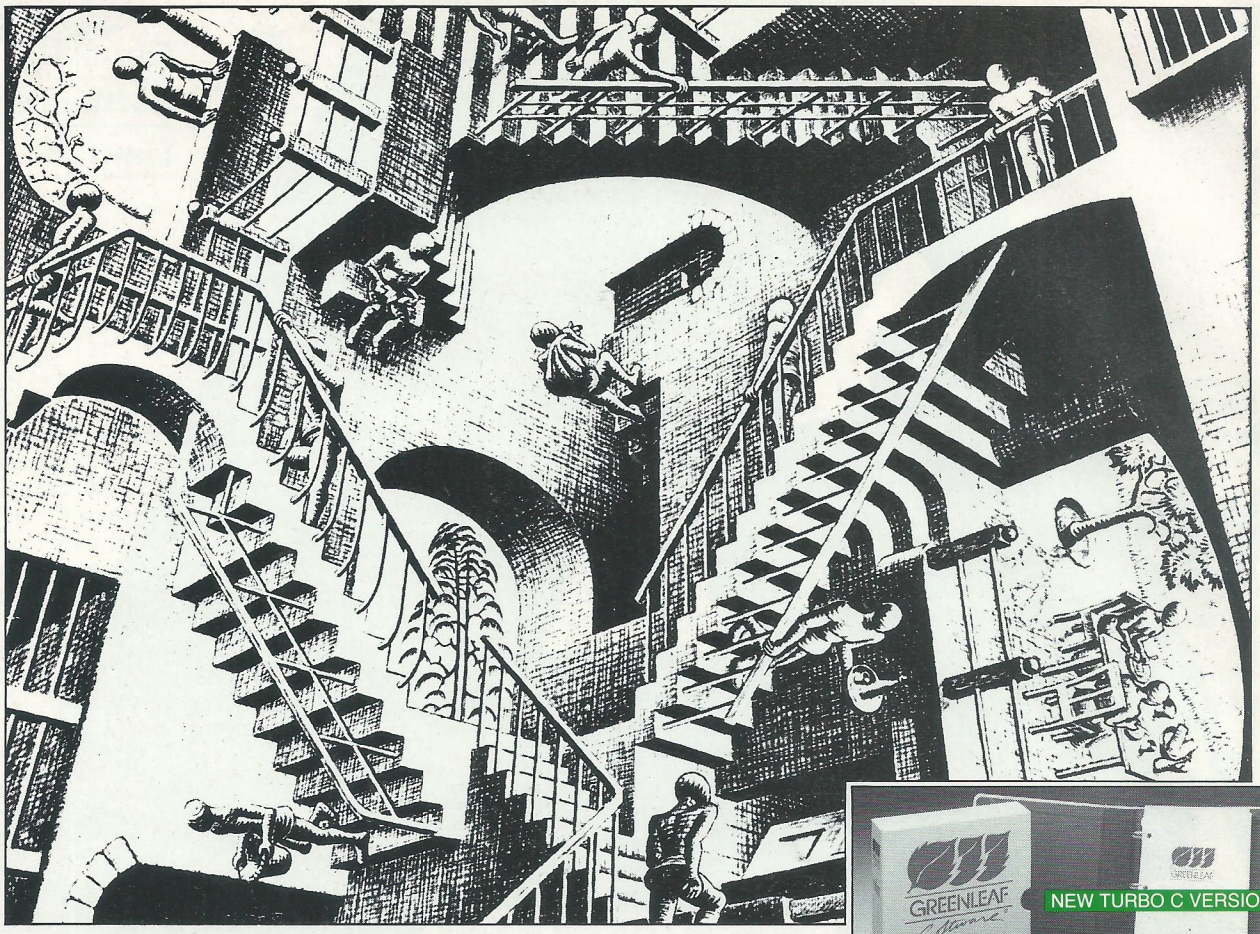

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EXOTIC LANGUAGE OF THE MONTH CLUB

Beyond text editors with VAXTPU

By Leonard Struttmann

The VAX Text Processing Utility (VAXTPU) has been used to create remarkable text editors, but its usefulness extends far beyond that. This article introduces the elements of VAXTPU's powerful, structured programming language and gives you a set of sample procedures that illustrates how VAXTPU can also be a simple yet powerful data base report generator.

VAXTPU is used to develop text-processing interfaces. That doesn't sound very exciting until you realize that a text-processing interface may be anything from a customized text editor for a specific application to something as sophisticated as a data base manager. This diversity is achieved through a powerful structured programming language that includes a rich set of built-in procedures.

Theoretically, you could use VAXTPU to create an entirely new text-processing interface from scratch. The result would be your own customized text editor. It would also be a waste of time since VAXTPU comes with two interfaces already programmed in VAXTPU. One emulates the venerable EDT editor. The other implements the Extensible VAX Editor (EVE), an exceptionally easy yet powerful full-screen editor. EVE's features include multiple open files and text windows.

Either EDT or EVE can be customized or extended to meet your interface needs. I will illustrate the basics you need to use the rich VAXTPU programming language to extend the EVE interface and include your very own text-processing functions.

One of VAXTPU's unique features is that it has no explicit statements to declare the data types of variables. In fact, variables may have any of VAXTPU's data types, and can even change the data types in midprogram.

The data type of a variable is set when that variable is used on the left-hand (result) side of an assignment statement. It is set to the type that results from the expression on the right-hand side of the assignment. For example, the following assignment not only assigns the value of 12346 to the variable *b_count*, but it also defines the variable *b_count* to be of type *INTEGER:*

```
b_count := 12346;
```

With this freedom in defining data types comes a responsibility for the programmer because VAXTPU's built-in procedures expect and return parameters of specific data types. The data types used by VAXTPU include:

- *INTEGER*: Whole numbers from -2147483648 to +2147483647.
- *STRING*: Character data. A string may be from 0 to 65,535 characters long.
- *BUFFER*: A text work space used to hold and manipulate text records. All editing, except for certain string operations, is done using buffers. Files are read into buffers, which may be mapped to windows for display on the user's terminal while being updated, then are written back out to text files.
- *WINDOW*: A specific region of the user's terminal screen used for text display. Windows may be created, sized, mapped to specific buffers, and deleted.
- *MARKER*: A pointer to a specific character location within a buffer. A marker may be assigned different video attributes for display on the user's terminal, such as blinking, bold, reverse-video, or underline.
- *RANGE*: All characters between two specific markers, including the characters associated with the markers. Ranges may also be assigned different video attributes for display on the user's terminal.
- *PATTERN*: A template for a sequence of characters to be searched for within a buffer. Several VAXTPU built-in procedures and operators are used exclusively when creating patterns. Patterns are handy for doing wild card-type searches. For example, the pattern variable *ur_pat* could be used to search for any string that begins with a less-than sign (<) and ends with a greater-than sign (>):

```
ur_pat := '<' & MATCH( '>' );
```

In this example, the pattern operator ampersand (&) is used with the VAXTPU built-in procedure *MATCH( )* to define the pattern.

Absent from this list of data types are such favorites as floating-point numbers and arrays. (Since VAXTPU is a text-processing language, I presume the developers deemed floating-point unnecessary.) However, programs written in other languages can be accessed through the built-in procedure *CALL_USER*. Floating point can be used, but not without some difficulty. Buffers can be thought of as arrays of text records, although accessing the data via buffers is not as convenient as conventional indexing.

The VAXTPU statements that control the execution of a VAXTPU program are similar to those found in other high-level, structured programming languages. The following are the most commonly used statements.

Procedure statements. The *PROCEDURE*, *ENDPROCEDURE*, *LOCAL*, *ON_ERROR*, and *ENDON_ERROR* reserved words are used to collect a set of VAXTPU statements into a callable routine, define local variables, and define exception processing. The syntax is:

```
PROCEDURE procedure_name
  [(parameter-list)]
    [LOCAL variable_list;]
    [ON_ERROR
       statements;
    ENDON_ERROR;]
    statements;
    ENDPROCEDURE;
```

LOCAL is optional and is VAXTPU's sole variable declaration statement. It defines variable identifiers whose scope extends only to this procedure and to procedures called from this procedure. Global variables are implicitly declared by their use in assignment statements.

ON_ERROR and ENDON_ERROR are also optional and define the processing desired in the event of a VAXTPU-detected error condition. (An example could be a "String Not Found" error be-

ing returned when using the built-in *SEARCH* procedure.)

Interactive access to user-written procedures from EVE is gained with a special command key called the *DO* key. This command makes development and testing easy since the procedures can be compiled and invoked directly from the EVE editor. Even built-in VAXTPU procedures and assignment statements may be executed interpretively in this manner.

Assignment statements. These statements are used to set a value to a variable while implicitly defining the data type of that variable. The syntax is:

```
variable_name := expression;
```

Loop statements. The *LOOP, EXITIF,* and *ENDLOOP* reserved words are used to define a group of VAXTPU statements that will be iteratively executed. The syntax is:

```
LOOP
   [statements;]
   EXITIF conditional_expression;
   [statements;]
ENDLOOP;
```

The statements between *LOOP* and *ENDLOOP* are executed until the result of the conditional expression is true. Note that any statements between *EXITIF* and *ENDLOOP* are not executed after the conditional expression is returned true.

Conditional statements. The *IF, THEN, ELSE,* and *ENDIF* reserved words are used to define groups of VAXTPU statements that will be conditionally executed. The syntax is:

```
IF conditional_expression THEN
   [statements;]
[ELSE
   statements;]
ENDIF;
```

Case statements. The *CASE, FROM, TO, INRANGE, OUTRANGE,* and *ENDCASE* reserved words are used to define groups of VAXTPU statements that will be conditionally executed. The syntax is:

```
CASE variable FROM lower_bound TO
upper_bound
   [case_id_1] : statements;
   [case_id_2] : statements;
    .
    .
   [case_id_n] : statements;
   [INRANGE] : statements;
   [OUTRANGE] : statements;
ENDIF;
```

VAXTPU's *case* construct is similar to the ordinary *case* selector found in other languages. First, in defiance of my earlier syntax examples, the square brackets surrounding the preceding *case* identifiers are a required, not optional, part of the syntax. Multiple *case* identifiers may be listed within each set of brackets, separated by commas.

However, the *case* selectors *INRANGE* and *OUTRANGE* are optional. *INRANGE* will match any *case* within the range of *upper_bound* to *lower_bound* that does not have an explicit *case* identifier listed, and *OUTRANGE* matches anything not within the bounds.

Additionally, the *case* identifiers are restricted to being integer constants or one-character string constants.

Complementing the VAXTPU data types and control statements are 92 built-in procedures (Table 1) that allow file access, manipulation of the various data types, and control of the user's terminal environment. Obviously, I cannot detail all of these procedures here, but I'll describe those I have found most useful in my work.

BEGINNING_OF and *END_OF* each return a marker that corresponds to the first and last positions, respectively, of a buffer or range. They are used in the form:

```
marker := BEGINNING_OF( {buffer |
   range} );
marker := END_OF( {buffer | range} );
```

COPY_TEXT places a copy of the specified string, range, or buffer into the current buffer at the current cursor position. Similarly, the built-in *MOVE_TEXT* copies the specified text, then

VAXTPU built-in procedures

ADJUST_WINDOW
ANCHOR
ANY
APPEND_LINE
ARB
ASCII
ATTACH

BEGINNING_OF

CALL_USER
CHANGE_CASE
COMPILE
COPY_TEXT
CREATE_BUFFER
CREATE_PROCESS
CREATE_RANGE
CREATE_WINDOW
CURRENT_BUFFER
CURRENT_CHARACTER
CURRENT_COLUMN
CURRENT_DIRECTION
CURRENT_LINE
CURRENT_OFFSET
CURRENT_ROW
CURRENT_WINDOW
CURSOR_HORIZONTAL
CURSOR_VERTICAL

DEFINE_KEY
DELETE

EDIT
END_OF
ERASE
ERASE_CHARACTER
ERASE_LINE
EXECUTE
EXIT
EXPAND_NAME

FAO
FILE_PARSE
FILE_SEARCH
FILL

GET_INFO

HELP_TEXT

INDEX
INT

JOURNAL_CLOSE
JOURNAL_OPEN

KEY_NAME

LAST_KEY
LEARN_BEGIN
LEARN_END
LINE_BEGIN
LINE_END
LOOKUP_KEY

MAP
MARK
MATCH
MESSAGE
MOVE_HORIZONTAL
MOVE_TEXT
MOVE_VERTICAL

NOTANY

POSITION

QUIT

READ_CHAR
READ_FILE
READ_KEY
READ_LINE
REFRESH
REMAIN

SAVE
SCAN
SCANL
SCROLL
SEARCH
SELECT
SELECT_RANGE
SEND
SEND_EOF
SET
SHIFT
SHOW
SPAN
SPANL
SPAWN
SPLIT_LINE
STR
SUBSTR

TRANSLATE

UNDEFINE_KEY
UNMAP
UPDATE

WRITE_FILE

Table 1.

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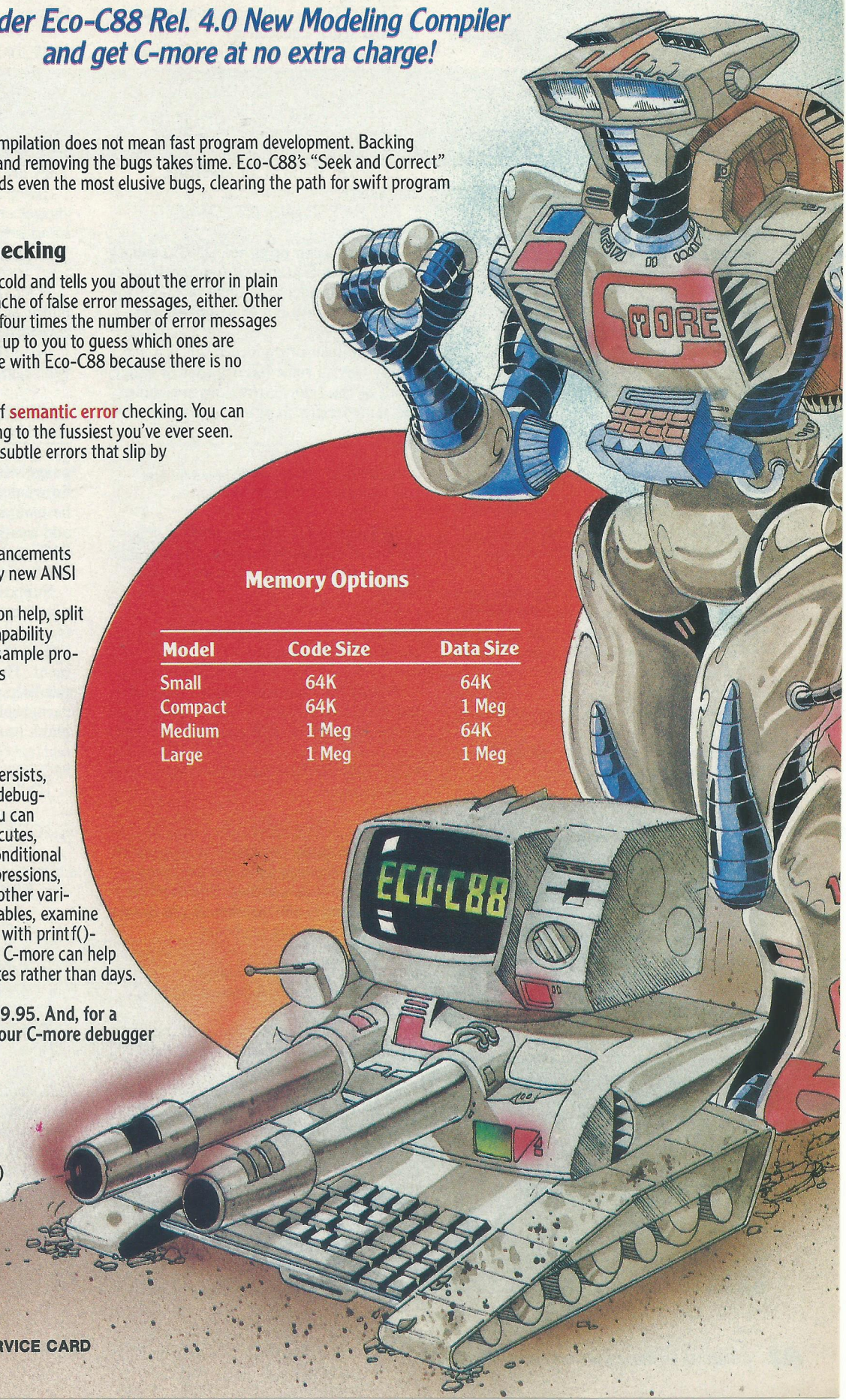

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deletes the original text. Their formats are:

```
COPY_TEXT( {string | range | buffer } );
MOVE_TEXT( {string | range | buffer } );
```

CREATE_BUFFER is used to define a new buffer for text editing, with the specified name. This buffer may be created empty or you may read into it the contents of a file. *CREATE_BUFFER* optionally returns a value of type *buffer* that may be used later in the program to refer to the newly created buffer. *CREATE_BUFFER* is used in the form:

```
[buffer := ]CREATE_BUFFER( buffer_
   name_string [,filename] );
```

CURRENT_LINE and *ERASE_LINE* are used to refer to the line of text that is currently being edited in the current buffer. *CURRENT_LINE* returns a copy of the current line as a string. *ERASE_LINE* deletes the current line and optionally returns it as a string. Their formats are:

```
string := CURRENT_LINE;
[string := ]ERASE_LINE;
```

EDIT is a powerful procedure that allows you to perform multiple editing functions upon string variables. The string that you wish to edit is passed to *EDIT*, along with one or more keywords that define what actions to take and how to handle quotation marks. *EDIT* is used in the format:

```
EDIT( string, keyword1[,...][keyword2]);
```

where *keyword1* can be any of the following, separated by commas.

Sample USED_BY file

INITIAL_POS_EAST	NAVIGATION
INITIAL_POS_EAST	OUT_DISPLAY
INITIAL_POS_NORTH	NAVIGATION
INITIAL_POS_NORTH	OUT_DISPLAY
INITIAL_REST_COUNT	RESTAURANT_SELECT

Figure 1.

Sample DESCRIPTION file

INITIAL_POS_EAST

Auto's initial east position in degrees.

INITIAL_POS_NORTH

Auto's initial north position in degrees.

INITIAL_REST_COUNT

Initial number of restaurants the vehicle will visit.

Figure 2.

COLLAPSE. Deletes all tab and space characters.

COMPRESS. Replaces multiple or sequences of tab or space characters with a single-space character.

TRIM. Deletes all leading and trailing tab and space characters.

TRIM_LEADING. Deletes all leading tab and space characters.

TRIM_TRAILING. Deletes all trailing tab and space characters.

UPPER. Returns all uppercase characters.

LOWER. Returns all lowercase characters.

INVERT. Toggles the case of all characters.

keyword2 can be either ON (to signify that all quotation marks and apostrophes are to be considered quotes) or OFF (to say that they are not to be considered quotes).

The built-in procedure *FILL* is a handy way to reformat a buffer or range so all of the reformated lines are about the same length. It is used with the format:

```
FILL( {buffer | range}, word_separators,
   l_margin, r_margin );
```

INT and *STR* are the familiar converters of strings to integers and integers back to strings. They are used in the forms:

```
integer := INT( string );
string := STR( integer );
```

POSITION is used to move the editing cursor position to a buffer, marker, range, or window. It is used in the form:

```
POSITION( {buffer | marker | range |
   window } );
```

READ_LINE displays an optional prompt string on the user's output device, reads the response from the keyboard, and returns it as a string. You can optionally specify the number of characters to be read from the keyboard.

```
[response_str := ]READ_LINE
   [( prompt_str [,response_length] ) ];
```

SEARCH returns a range that corresponds to the first occurrence of the specified string or pattern. You must supply *keyword1* to specify whether the search is to be in the *FORWARD* or *REVERSE* direction. You may supply *keyword2* to indicate whether there needs to be an *EXACT* match in terms of character case. *keyword2* may also be set to *NO_EXACT* if an exact match is not needed:

```
range := SEARCH( {string | pattern },
   keyword1 [, keyword2] );
```

SPLIT_LINE breaks the line currently being edited into two lines. This procedure is similar to adding a *Carriage_Return*, *Line_Feed* at the current editing position. It is used in the format:

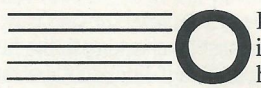
```
SPLIT_LINE;
```

LENGTH and *SUBSTR* are the familiar string operations that return the length of a string and the specified subset of a string or range, respectively. They are used as:

```
integer := LENGTH( string );
string := SUBSTR( {string | range},
   start_position, length );
```

WRITE_FILE writes the specified buffer or range into the specified file. It is used in the format:

```
WRITE_FILE( {buffer | range}, filename );
```



OK, so VAXTPU is a structured, high-level language with a bunch of funny built-ins. So what can you do with it? One of the best ways to begin with VAXTPU is to add a customized editing function to the EVE text-processing interface, which is written in VAXTPU.

Suppose, in the course of updating a document with EVE, you find yourself frequently needing to skip to the first line of the next paragraph in your document. The following VAXTPU procedure can help you do just that (assuming each paragraph is separated from others by blank lines):

```
PROCEDURE eve_next_paragraph
   LOCAL cline;   ! The current line that
      we're editing
   LOOP
      cline := CURRENT_LINE;   ! Get
      the current line
      EDIT( cline, TRIM );   ! Trim off all
      spaces
      MOVE_VERTICAL( 1 );   ! Move
      cursor down to next line
      EXITIF ( cline = "" );   ! Quit if
      previous line was blank
   ENDLOOP;
ENDPROCEDURE;
```

In the *LOOP* in *eve_next_paragraph*, the current line of text in the current active buffer is assigned to the string variable *cline*. All of the spaces are then trimmed from this string, the cursor is moved down to the next line, and *cline* is tested to see if it was a blank line.

The EVE interface can be extended by adding this procedure to its repertoire of

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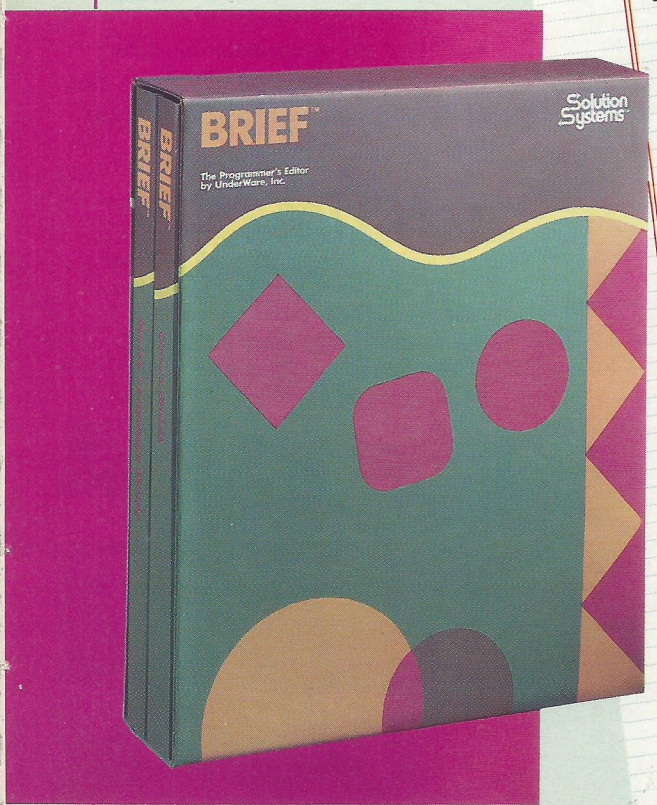

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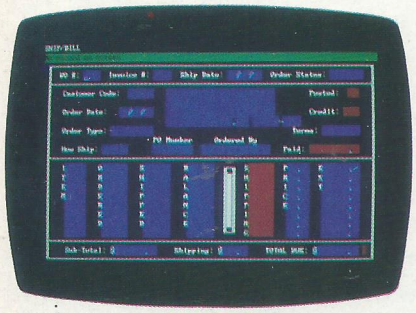

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```
!*************************************************************************
PROCEDURE          eve_gen_report
!       This procedure generates the data dictionary report file
!       OUTPUT.MAS from the master input files GENERATED_BY.MAS,
!       USED_BY.MAS, and DESCRIPTION.MAS
!*************************************************************************
  LOCAL cline,              ! current line in buffer gen_buf
                out_buf,                ! output buffer
                var_name;               ! variable name


  tabb := "          ";   ! global variable for blank spaces at
                          ! beginning of each output line

  out_buf := CREATE_BUFFER( "OUTPUT.BUF" );
  gen_buf := CREATE_BUFFER( "GEN_BY_BUFFER", "GENERATED_BY.MAS" );
  use_buf := CREATE_BUFFER( "USE_BY_BUFFER", "USED_BY.MAS" );
  des_buf := CREATE_BUFFER( "DESC_BUFFER", "DESCRIPTION.MAS" );

  LOOP
        POSITION( BEGINNING_OF( gen_buf ) );
        EXITIF ( GET_INFO( CURRENT_BUFFER, "record_count" ) = 0 );
        cline := CURRENT_LINE;
        get_token( cline, 1, var_name );
        POSITION( END_OF( out_buf ) );
        COPY_TEXT( tabb + var_name );
        SPLIT_LINE;
        SPLIT_LINE;
        put_gen_used( var_name );
        put_description( var_name );
  ENDLOOP;

  WRITE_FILE( out_buf, "OUTPUT.MAS" );
  ENDPROCEDURE;
```

Listing 1.

```
!*************************************************************************
PROCEDURE       put_gen_used( var_name )
!       This procedure builds the "Generated by:" and "Used by:"
!       fields in the data dictionary report output buffer.
!*************************************************************************
       LOCAL   gend_by,
                       output_line,
                       used_by;

       gend_by := "";
       used_by := "";

       get_gend_used( gen_buf, var_name, gend_by );
       get_used_used( use_buf, var_name, used_by );
       output_line :=  tabb + "Generated by: " + gen_by;
       pad( output_line, 40 );
       output_line := output_line + "Used by: " + used_by;
       COPY_TEXT( output_line );
       SPLIT_LINE;

       LOOP
              get_gend_used( gen_buf, var_name, gend_by );
              get_used_used( use_buf, var_name, used_by );
              EXITIF (gend_by = "") AND (used_by = "");
              output_line :=  tabb;
              pad( output_line, 23 );
              output_line :=  output_line + gen_by;
              pad( output_line, 48 );
              output_line := output_line + used_by;
              COPY_TEXT( output_line );
              SPLIT_LINE;
       ENDLOOP;

       SPLIT_LINE;
       ENDPROCEDURE;
```

Listing 2.

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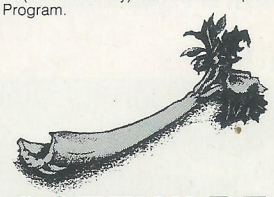

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editing commands. You could even map this procedure to its own function key to make it easier to invoke.

A more substantial illustration of VAXTPU programming can be found in the following case history. The company I work for writes a large amount of software for the U.S. government. We recently found ourselves with only two weeks to input, format, and publish a 500-page data dictionary. In this document we had to list each variable used in our application program and provide a textual description and list of the software functions that generated and used each variable.

Although the task was not particularly difficult, the extremely short deadline presented a real challenge. The large amount of time needed to set up a conventional data base, teach people to input the data, and generate a suitable report prevented us from going that route.

Instead, we instructed everyone to use his or her favorite text editor to start inputting data into three text files: GENERATED_BY, USED_BY, and DESCRIPTION. These files were produced with very little training. The data was separated from the variable name by several spaces (or a blank line, in the case of the description). Figures 1 and 2

```
!*****************************************************************************
PROCEDURE    get_gend_used( buffername, var_name, return_string )
!      This procedure returns the next "Generated by" or "Used by"
!      field associated with var_name from buffer buffername.
!*****************************************************************************
        LOCAL   cline,
                search_range;  ! range returned from SEARCH built-in

        ON_ERROR
                IF ( error = tpu$strnotfound ) THEN
                        search_range := 0;
                ENDIF;
        ENDON_ERROR;

        return_string := "";
        POSITION( BEGINNING_OF( buffername ) );
        search_range := SEARCH( var_name, FORWARD );
        IF (search_range <> 0 ) THEN
                POSITION( search_range );
                cline := ERASE_LINE;
                get_token( cline, 2, return_string );
        ENDIF;
        ENDPROCEDURE;
```

Listing 3.

```
!*****************************************************************************
PROCEDURE    get_token( in_string, n , token_string )
!       This procedure returns the nth token from the
!       input string
!*****************************************************************************
   LOCAL counter,      ! These are local copies of the input
                 temp_str,       ! parameters that we can alter
                 space_index,  ! position of 1st space in temp_str
                 str_len;        ! length of string to extract

   temp_str := in_string;
   counter := n;
   LOOP
           EDIT( temp_str, TRIM );
           space_index := INDEX( temp_str, " " );
           EXITIF ( counter = 1 );
           str_len := LENGTH( temp_str ) - space_index;
           temp_str := SUBSTR( temp_str, space_index, str_len );
           counter := counter - 1;
   ENDLOOP;

   IF ( space_index = 0 ) THEN
           token_string := temp_str;
   ELSE
           token_string := SUBSTR( temp_str, 1, space_index - 1 );
   ENDIF;

   ENDPROCEDURE;
```

Listing 4.

show excerpts from sample USED-BY and DESCRIPTION files.

Standard VAX utilities were then used to merge the individual lists into three master lists and sort the GENERATED_BY and USED_BY lists. The final report was generated using a set of VAXTPU procedures similar to those shown in Listings 1-5.

The top-level procedure (*eve_gen_report*) starts by creating an empty buffer in which to place the report (*out_buf*), then continues by reading the three master lists into the three buffers called *gen_buf, use_buf*, and *des_buf*. It then enters its main loop and iteratively performs four actions:

1. Checks to see if it is done by testing for any more records in *gen_buf*.
2. If not, it retrieves the next variable name from *gen_buf*.
3. Copies the variable name into the output buffer.
4. Calls two procedures, *put_gen_used* and *put_description*, to build the other fields in the output buffer.

When *eve_gen_report* is done, it merely needs to write the output buffer out to the file OUTPUT.MAS with a call to the VAXTPU built-in WRITE_FILE.

As we've seen, VAXTPU provides an interesting alternative for processing textual data. File I/O is easy and VAXTPU's extensive built-in procedures provide a powerful set of tools for manipulating text. Programming in VAXTPU is fast, and the interactive debugging provided by the EVE interface makes the development almost painless.

I have used VAXTPU programs to format technical publications, generate column-oriented reports from line-oriented input data, recursively analyze compiler listings to produce hierarchical calling trees, and even estimate module memory- and stack-size requirements.

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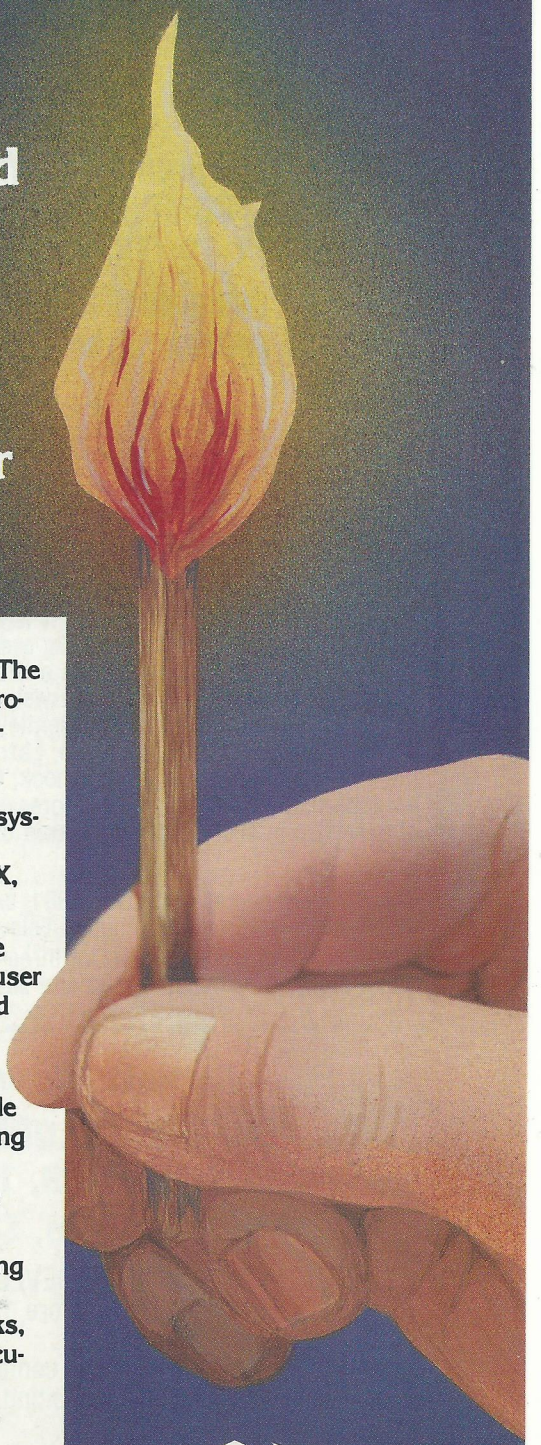

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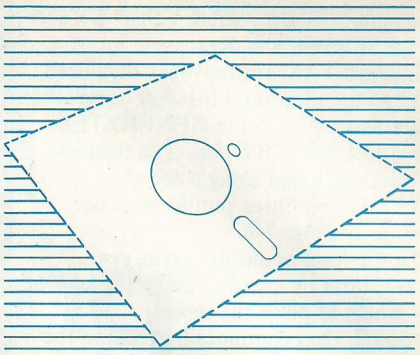

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ate applications. I would love for someone to take the basic concepts provided by VAXTPU and extend them to include support for other high-level data structures (such as floating-point numbers and arrays). To me, that would be close to an ideal programming environment.

Leonard Struttmann has a B.S. degree in electrical engineering from the University of Missouri at Rolla, Mo. He has written real-time avionics software for more than eight years for McDonnell-Douglas, Sperry Corp., and Rockwell. His work includes providing support and productivity tools for use in software development VAX minicomputers.

```
!*****************************************************************************
PROCEDURE         put_description( var_name );
!    This procedure builds the "Description"  fields in the
!    data dictionary report output buffer.
!*****************************************************************************
  LOCAL cline,
                  des_range,        ! description to be
                                    !    transferred
                  m1,               ! marker at beginning of
                                    !    description
                  m2,               ! marker at beginning of
                                    !    description
                  search_range;     ! range returned from SEARCH
                                    !    built-in

  ON_ERROR
          IF ( error = tpu$strnotfound ) THEN
                  search_range := Ø;
          ENDIF;
  ENDON_ERROR;

  POSITION( BEGINNING_OF( des_buf ) );
  search_range := SEARCH( var_name, FORWARD );
  IF (search_range <> Ø ) THEN
          POSITION( search_range );
          cline := ERASE_LINE;      ! delete the variable name
          cline := ERASE_LINE;      ! delete the blank line
          m1 := MARK( NONE );       ! mark beginning of description

          LOOP                      ! find next blank line
                  MOVE_VERTICAL( 1 );
                  cline := CURRENT_LINE;
                  EDIT( cline, TRIM );
                  EXITIF ( cline = "" );
          ENDLOOP;

          m2 := MARK( NONE );       ! mark end of description
          des_range := CREATE_RANGE( m1, m2, NONE );
          POSITION( END_OF( out_buf ) );
          MOVE_TEXT( des_range );   ! move the description to
                                    !    out_buffer
  ENDIF;
  ENDPROCEDURE;
```

Listing 5.

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By Johanna Kleppe

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C Dick, C Jane, C Spot...

C Spot Run is a set of routines with text windowing, simple graphics, and string manipulation. $15; $50 (with source code); $75 (source code and license for commercial use).

New Dimension Software, 23 Pawtucket Dr., Cherry Hill, N.J. 08003, (609) 424-2595.

CIRCLE 130 ON READER SERVICE CARD

SolveIT!

SolveIT is a numerical analysis tool with a mouse interface and an overlay structure for memory conservation, all supplemented by a technical reference manual. $129

Structured Scientific Software, 1509 Queen Ave. SW, Albany, Ore. 97321, (503) 926-8599.

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Microsoft maintains

Microsoft's FORTRAN Optimizing Compiler v. 4.01 has faster *LOG* and *EXP* functions. Upgrade to v. 4.01 free to v. 4.0 owners, $150 to owners of earlier versions.

Microsoft Corp., 16011 NE 36th Way, Box 97017, Redmond, Wash. 98073-9717, (206) 882-8080.

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Meridian Software Systems, 23141 Verdugo Dr., Ste. 105, Laguna Hills, Calif. 92653, (714) 380-9800.

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Public display of a function

C-Display Manager v. 3.2 has a screen generator and demo utility (*DisplayExpress*), and a library of display and graphics management functions (*C-Display Librarian*).

Sydetech, 43-23 Colden St., #17C, Flushing, N.Y. 11355, (718) 886-0221.

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Zeos International, 530 5th Ave. NW, St. Paul, Minn. 55112, (612) 633-4591.

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What's up, AVDOC?

AVDOC is an on-screen reference guide for C programmers with a pop-up calculator that figures decimal, hexadecimal, octal, and ASCII values. $49

Avocet Systems, 120 Union St., P.O. Box 490, Rockport, Maine 04856, (800)448-8500.

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MICRO/C-Z8, a support tool for Zilog Z8, has C access to all on-chip peripherals by name and run-time exception checking of math and memory access operations. $750

Micro Computer Control, P.O. Box 275, Hopewell, N.J. 08525, (609) 466-1751.

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Ecosoft on the rise

Ecosoft's v. 4.0 of the *Eco-C88* C compiler uses syntax parsing techniques and provides a user-selectable lint facility. *C-More* is a source code debugger used by menu or Quickkeys selection. $99.95 (Eco-C88); $49.95 (C-More)

Ecosoft Inc., 6413 N. College Ave., Indianoplis, Ind. 46220, (316) 255-6476.

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Toolboxes are opened

Turbo BASIC Toolboxes are for data base, editor, and telecommunications development. $99.95

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```
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{
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}
i_search()
{
 int c, len;
 string pattern;
 save_position();
 while (c != '\E') {
   message(strcat("Incr Search -- ", pattern));
   if ((c = get_tty_char()) == '\b') {   /* backspace */
     if ((len = strlen(pattern)) > 1)
       pattern = substr(pattern, 1, len - 1);
     else
       pattern = "";
     restore_position();          /* go to where we started from */
   }
   else if (c == 7) {             /* <CTRL> G means abort */
     for (len = strlen(pattern); len > 0; len = len - 1)
       restore_position();        /* restore to start position */
     break;
   }
 .......
```

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Support: Telephone support available

Emacs, like UNIX, Forth, LISP, and a few others, is one of those extensible, interactive software systems that tends to incite strong loyalty in programmers. Basically, it is a screen-oriented text editor that gives the user power to define complex editing operations and set up mappings from keystrokes to operations. With Emacs, the user can associate nearly any sequence of keystrokes with nearly any editing operation. In fact, Emacs is as much a language for designing editors as it is an editor itself.

Emacs traditionally has had strong ties to the LISP culture, and the language used to build complex editing commands within Emacs is very much like LISP. Since Richard Stallman invented Emacs at Massachusetts Institute of Technology, Cambridge, Mass., in the early 1970s, several recreations have appeared. John Gilmore's freeware GNUemacs is popular, as is another free version called microEMACS, written by David Conroy.

The UniPress Emacs discussed in this review is based on a version written by James Gosling when he was at Carnegie-Mellon University, Pittsburgh, Pa., to run under the UNIX operating system. UniPress has developed versions to run under either UNIX or MS-DOS.

Before you begin to think the title of this article contains a typographical error, I should explain that C-macs is the name UniPress gives to a package of C-oriented extensions to Emacs available since early 1987. In this review, Emacs will mean the underlying editor and C-macs the extension package, although sometimes the distinction is fuzzy. Besides strictly focusing on the C-macs package, this review also includes some evaluation of UniPress Emacs and compares Emacs and more traditional screen-oriented editors such as vi.

For a single-user computer such as an IBM-PC/AT or a Sun 3 workstation, a binary license for C-macs costs $645, plus 25% for support (including a year's free updates). The underlying Emacs is included in the price, and if you already have it a credit is available. Although UniPress Emacs is available for MS-DOS, you must have some version of UNIX (such as XENIX) to run C-macs. The version I tested was the one for the Sun 3 workstation.

What kind of C-oriented extensions does C-macs provide? According to the blurb in the UniPress Emacs newsletter, C-macs includes:

- A menu user interface
- Automatic expansion of C control structures
- An electric C mode which provides automatic indentation, parenthesis matching, etc.
- A tags facility similar to that in vi for keeping track of which functions are in which files
- A keyword description data base
- Compile-time aids such as an error message parser.

Furthermore, the user's manual states, "you do not need to be familiar with Emacs to Use this C-macs." This sounds promising. I do a lot of C programming using vi as the editor and have often wished for a little more C-specific intelligence in the editor. The question is, how does this work in practice?

First of all, the documentation is excellent. The C-macs user's manual can be read as a tutorial and the Emacs reference guide has over 700 pages of Emacs function descriptions and variables (in alphabetical order) in a format similar to UNIX man pages. The C-macs user's manual is self-contained and describes the Emacs commands needed for basic editing operations such as creating and deleting buffers and windows, moving the cursor around, and searching, deleting and inserting text, as well as the C-specific C-macs features.

Emacs is fundamentally different from vi in that vi distinguishes between a command mode and an insert mode. During insert mode in vi, a typed character is inserted into the current buffer. In vi command mode, the same character may be used to signify some command such as moving the cursor. For example, in vi the keystroke "n" means either to insert an "n" into the buffer or to find the next occurrence in the buffer of a previously specified search string. Which of these meanings is applicable depends on if the user is currently working in insert mode.

Emacs does not have this distinction between modes. Typing "n" only means "insert 'n' into the buffer." In Emacs, therefore, all printing characters are unavailable for use as commands; escape sequences and control characters must be used instead. The default Emacs keystroke sequence for "find the next occurrence in the buffer of the previously specified search string" is ^s-return (where ^s designates Control-s). To execute this common operation in Emacs requires three keystrokes from distant parts of the keyboard instead of a single keystroke, as in vi.

In a similar way, most Emacs commands take longer to type than the corresponding vi commands. This makes the Emacs user interface considerably less efficient than vi, although some programmers are not bothered by extra typing.

To this criticism the Emacs enthusiast will respond that it is easy to modify the key bindings to make them mean anything you want. This is true, but if one gets used to an overcustomized, personal version of Emacs, the benefits of standardization are lost and you are unable to function on a new system until you have customized it.

On the positive side, Emacs has an excellent windowing facility. Under Emacs it is easy to split the display screen into two or more independent windows and use them to display several files or several parts of the same file. This feature is powerful, especially if an operating system does not provide a user interface with windows. The Sun 3 workstation I

use has a convenient way of opening new windows on the display screen, running separate tasks in them, and moving text from window to window. Although this feature is provided by the Suntools user interface software that comes with the workstation, the Emacs windows were a convenient supplement.

I found Emacs' treatment of the *newline* character to be more consistent and natural than vi's. In Emacs, the *newline* character is treated as any other; the cursor may even be positioned at it. To join two consecutive lines in Emacs it is therefore necessary only to position the cursor over the *newline* character at the end of the first line and type ^d to delete that character. In vi, a special *Join* command is required since the cursor cannot be placed at a *newline*.

After skimming through the user's guide (and armed with the reference card), I began to experiment with the system. Emacs and C-macs loaded from cartridge tape to disk with no trouble, although I was somewhat surprised to see that the program and data files (I did not have source) used over 5 MB of disk space compared to less than a quarter of a megabyte for UNIX vi. The start-up time for C-macs was also considerably greater than the start-up time for vi (18 seconds vs. 5 seconds). The 68020-based Sun is considerably more powerful than an IBM PC/AT, and I wonder what the start-up time is on an IBM PC/AT.

I had a few surprises trying the C-macs features. According to the manual, "An on-line tutorial will teach you how to use C-macs. To run this tutorial, first start C-macs as described above. Then press ^_ (control-underscore) followed by a t." When I tried this, I got an error message saying that the C-macs tutorial file was not present. According to UniPress president Mark Krieger, the company does not provide a tutorial for C-macs. A tutorial file for the underlying Emacs is present, however.

I then experimented for a while with the standard Emacs commands for cursor movement, window manipulation, string search, etc. These worked fine. I tried the *shell* command, which executes a new copy of the shell, putting its input and output into a new buffer. This command worked until I exited from the shell by typing control-d. I then got the message that the process was wedged (whatever that means) and a query as to whether I wanted to unblock it. Neither a positive nor a negative response had any effect, and the only way I could get out was to exit my log-in session via the Sun Suntools menu.

The next day another user of the system complained that the system was sluggish, and I discovered that the C-macs process was still running in the background, using large amounts of CPU. I had to kill it with a UNIX *kill* command. UniPress said this is a known bug and they are working on it.

One useful feature of Emacs is the *help* command. Typing ^_a <string> displays the names of all commands containing <*string*>. Typing ^_d <command-name> displays a short description of the named command. I typed ^_a brace and noticed that one of the commands listed was named *forward-brace*. I tried ^_d forward-brace and got the message "No help for forward-brace." I don't know why the ^_d gives help for some commands and not others.

The people at UniPress explained that descriptions are only available for the more obscure commands (the ones even experienced users would need help with). A data base with a complete set of command descriptions would take up too much room. This is a reasonable explanation, but it does not help the novice.

An interesting documented feature of C-macs allows you to compile the program in a buffer and collect the error messages automatically in another buffer. Typing ^x^n is then supposed to parse the next error message and set the cursor to the appropriate line in the source file. This is a common situation in which it is advantageous to be able to look at two files (the source file and the error file) at the same time.

I wrote a test program that contained three errors: a preprocessor error (*#defune X 1*), a compiler syntax error (*a===b;*), and a linker error (*pruntf("x");*). All three errors appeared in the buffer in turn, but the ^x^n error message parser found only one of them. If the program contained just the preprocessor error or linker error, C-macs

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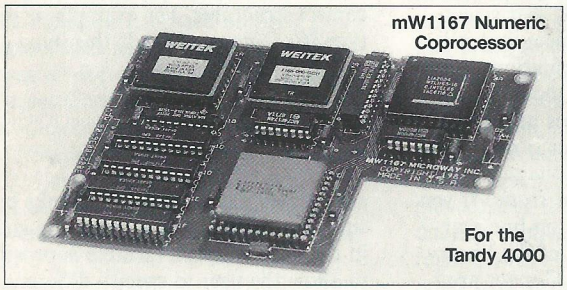

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would report "No Errors," even though the error message was in the buffer. To catch these different error messages it is necessary to modify the error-parsing algorithms. The extensibility of Emacs allows this to be done without source code.

Another feature of C-macs is the ^x^d keystroke sequence that prints one-line and longer descriptions of common C keywords. One need only put the cursor at the word to be described and type ^x^d. I put the cursor at an occurrence of the token *char* and got a nice description of the meaning of the keyword in C. Likewise, I got descriptions of the words *int, if, switch,* and all the library routines I tried, but was unable to get any help on the terms *ifdef, void, register, static, struct, case, default, break,* and *sizeof.*

The data base is incomplete, but it is easy for the user to add definitions to it. The explanation that only the more obscure terms are defined does not hold water here; the programmer is more likely to know the meaning of the terms *int* or *if* than the terms *void* or *static.* If you have a UNIX system with on-line manual pages, the descriptions of the library routines available through C-macs are redundant.

C-macs gives the user the option of executing some common commands via a menu rather than typing the commands. The keystroke sequence to activate the menu is Escape-m. I was confused because sometimes typing Escape-m produced a menu while at other times it did nothing. I finally noticed that for Escape-m to produce a menu, the mouse on the Sun must be touched after entering C-macs. Without moving the mouse cursor at least a fraction of an inch, the menu will not activate. I checked with UniPress on this problem and they could not duplicate it; either it was some peculiarity of my workstation or it had been corrected in the most recent version of the Emacs software.

One more peculiarity associated with menus occurs with windows. Ordinarily, moving the mouse cursor to a Suntools window will activate that window. Thus it should be possible to have one Suntools window running Emacs, another running a shell or some application program, another running vi, etc. Whenever a menu is up in an Emacs window, however, other Suntools windows not running Emacs cannot be activated. I have run many programs on the Sun under Suntools and have never seen one of these programs interfere with others in different windows in this way.

UniPress called this drawback a feature instead of a bug, but the explanation was not too clear to me. In any case, once the user is aware of the problem, it is a simple matter to kill the menu before moving to another window.

Finally, the statement in the newsletter that "all menu items can be bound to keys, and these bindings are shown in the menus" is incorrect. The key bindings are not shown in the menus.

One of the more confusing aspects of C is the C type declarator. C-macs provides a feature that allows the user to set the cursor at a type declarator and get an English-language description of the meaning of that declarator. For example, if you set the cursor at the declaration *int (*f[])();* C-macs will tell you: "declare *f* as array of pointer to function returning *int.*" The facility that does this is a public-domain C program called cdecl that is supplied with C-macs.

Another feature furnished by C-macs is a set of macros that expand into C control structures. For example, if you type *if(,* C-macs expands this into:

```
if() {

}
```

and allows you to fill in the blanks by positioning the cursor and inserting strings in the usual way. A variable is provided to allow the user to specify different styles such as:

```
if()
{

}
```

or:

```
if()
    {

    }
```

Unfortunately, not all of the expansions noted in the documentation work. For example, typing *elseif* is supposed to produce:

```
else if (){

}
```

but doesn't. There are also some undocumented expansions. For example, typing:

```
main(
```

expands to

```
main()
{

}
```

and typing the characters *argc* after the opening parenthesis immediately produces:

```
main(argc, argv)
int argc;
```

```
int argc;
char *argv[];
{

}
```

This is very convenient. Unfortunately, if the C-macs variable *elec-c-auto-close-paren* is set (which is always supposed to create parentheses and brackets in matching pairs), these expansions do not work correctly.

Some programmers write vi macros to produce keyword expansions similar to those just displayed, but the C-macs facility is somewhat more sophisticated than what can be done in vi; for example, C-macs will suppress expansion within a comment.

Support is a critical consideration in selecting software. I did not have the Emacs support option; nevertheless, when I called UniPress to discuss the minor problems I had, company representatives were very helpful. Their knowledgeable support person listened patiently to all my questions, offered suggestions and explanations, and took bug reports when necessary. (UniPress did not know I was reviewing the product.)

The basic idea behind C-macs is a good one: to provide an editing tool with built-in knowledge of the C programming language. The Emacs editor upon which C-macs is built is basically a sound one, although it seems to have some problems interacting with the Suntools windowing system. The organization and presentation of the Emacs/C-macs documentation is just right and serves both the beginner and the expert well.

I was somewhat disappointed by the many minor inconsistencies and omissions. The testing and quality assurance for the product should have caught more of these problems. However, since the product has been on the market less than a year, I would expect the quality to improve. I was very pleased with the level of telephone support.

If you know and like Emacs and do a lot of programming in C, C-macs may be for you. You need to decide whether the documentation, support, and C language extensions make the $645+ for C-macs worthwhile compared to the several freeware versions of Emacs. If you are currently a vi user and are considering C-macs, you also need to consider the differences between vi (small and efficient) and Emacs (big and extensible).

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OPAL is advertised as a "batch executive language that gives you the control you need over the PC-DOS/MS-DOS environment." While this is true, OPAL is also an interpreter and prototyping aid with features to aid in entering data, defining custom menus, and developing your own shell.

The small-memory model (the default) handles programs that use up to 64K of data while the large-memory model uses all of the system memory. A setup file lets the OPAL user to control *trace, traceback,* and *fastio.* While OPAL is slow as an interpreter, a tokenizing compiler can be purchased for enhanced speed. (On some benchmarks the interpreter execution time was about 23 seconds, while the compiler time was 9 seconds.)

OPAL is delivered with several examples that show the user how to write OPAL programs, define and use menus, and create a custom shell that gives DOS a completely different feel. One of this shell's unusual features is that it does not replace COMMAND.COM but builds upon it. Commands are processed by the shell if it recognizes them, while unknown commands are simply handed to the DOS command interpreter. This feature permits renaming commands or removing them entirely.

As a programming language, OPAL has some of the characteristics of BASIC and C. Assigning a variable *X* the value of 1 is done by the statement *LET X = 1.* The *file open* function requires an argument of "r" or "w" (quotes included) to specify read or write mode. The BASIC-like *LET* is specified in the OPAL manual but seems to be optional in the interpreter (as in BASIC), but the compiler demands it.

An interesting fact about OPAL variable assignments is that the variable type is determined at run time. This means that in the statements *LET X = 1* and *LET X = 1.0* the variable *X* is first an integer and then a real number. This type of conversion is automatic and could potentially produce a problem since *LET X = 1/2* and *LET X = 1.0/2* give answers of 0 and 0.5. An OPAL programmer must be aware of this distinction while writing so subtle errors can be prevented.

In addition to *LET,* OPAL has *BREAK, CALL, CONTINUE, DATA, DECLARE, DEFINE, DO-END, DOS, GLOBAL, IF-THEN-ELSE, PRINT, PROC, REMOVE, RETURN, SELECT,* and *SHOW* statements.

The *BREAK* statement exits a loop created by a *DO-END* pair and accepts an optional parameter that is used with nested loops to control the level at which thebreak takes place. If no level is specified, the default is the lowest level.

The *CALL* statement comes in three varieties: *CALL OPAL* to call another OPAL program, *CALL SYSTEM* to execute an MS-DOS/PC-DOS internal command, and *CALL EXEC* to execute operating system external commands (.COM, .EXE, and .BAT files). For the *CALL OPAL* variant, the number of nested calls is limited to the lesser of the number of open files specified in CONFIG.SYS or 64. (Since five files are used by OPAL internally, the actual number is 57.) *CALL SYSTEM* loads the command processor and passes a command line with arguments to COMMAND .COM for processing, while *CALL EXEC* loads a program into memory and executes it.

OPAL may be overlaid by the child process created with *CALL EXEC* if there is not sufficient memory to permit both processes to be resident (controlled by a Boolean argument in the call). If OPAL is overlaid, control returns to DOS after the program is executed. If OPAL is not overlaid, control is returned to OPAL. If the global variable *SAVE_* is true, the screen is returned to its *pre-call* state.

The *CONTINUE* statement is executed conditionally to transfer control to the bottom of a *DO-END* block. The difference between *BREAK* and *CONTINUE* is that *BREAK* transfers control just past the *END* statement while *CONTINUE* transfers control just before the *END. Thus, BREAK* exits the loop while *CONTINUE* goes to the bottom of the loop, terminating the current iteration and starting the next one.

DATA is an output statement used to display a single variable type on the screen. *DATA* statements are confined to a *DO DATA* block I will describe later.

The *DECLARE* statement is used to allocate space for an array and optionally initialize it. An array can also be created by an initial reference to the largest element. Thus, *LET X[20] = 1.5* creates an array of 20 elements even if *X* has not

been formally declared. With this usage, the first reference must be to the upper bound of the array. The *DECLARE* initialization of an array is faster than using a *DO* loop.

The *DEFINE* statement is the workhorse for producing forms and menus with OPAL. Both forms and menus start with a *DEFINE* that lists the form or menu name and whether it is a form or a menu. Following this is a *BORDER* definition that specifies a position for the heading (left justified, centered, or right justified), heading string, border type, width, and height. Next is a *LABEL* with placement and text string arguments.

For a menu, a *CHOICE* option then indicates a number to return if this choice is selected, location of the choice in the border, a text string describing the choice, cursor movement information for moving around the menu, and the name of an optional help file to display if the user requests it. The choice substatement is repeated as needed up to 50 times.

Forms have *FIELD* statements (rather than *CHOICE*s) that denote placement of the field, a field number, type and length of the field, edit action, variable, help file, and value verification information to ensure that the user enters a valid value. The edit action permits the programmer to force case to upper or lower, justify, zero-fill numeric fields, and protect fields.

Both the form and the menu versions of *DEFINE* are terminated with *END*. For the user who depends heavily on menus and/or forms, a companion product, OPART, speeds up the generation of the code to handle these features by using functions keys to save typing in the information.

The *DO* statement comes in eight flavors. The simple *DO* does not form a loop but is used (with an *END* statement) to make compound statements, which is analogous to the *BEGIN-END* block in Pascal. The *DO* statement can be used to perform loops with *DO WHILE, DO UNTIL,* an incremental *DO (DO Y=1 TO 10 [BY step])*, a combination of incremental and conditional (*DO Y=1 BY 1 WHILE Y<100)*, incremental with a *NEXT* clause (*DO Z=1.001 NEXT Z*2 UNTIL Z>3)*, *DO IN* to test for set membership, and the *DO DATA* statement to print information on the screen with the *DATA* statement. An example of a *DATA* output loop is:

```
X=4.5
DO fn="CON" DATA WHILE X>5
X=X*1.02
DATA X
END
```

The *DOS* statement is used to leave OPAL and return to the operating system. A value for the system variable *ERRORLEVEL* may be specified to flag abnormal termination if OPAL is run from a batch file. The *GLOBAL* statement is used to make a local variable a global variable so it can be referenced in any routine. The *IF-THEN-ELSE* statement is used to control program flow and is used like the Pascal equivalent.

The *PRINT* statement is a more general output statement than the *DATA* statement and is not confined to a *DO-DATA* block. *PRINT* is almost identical to *PRINTF* in C except that the new line character is %n rather than \n. Executing the statements

```
LET age = 37
LET name = "George"
PRINT("%s is %d years
old.%n",name,age)
```

results in the the following line:

George is 37 years old.

If another %n were placed after the first, a blank line would also be printed.

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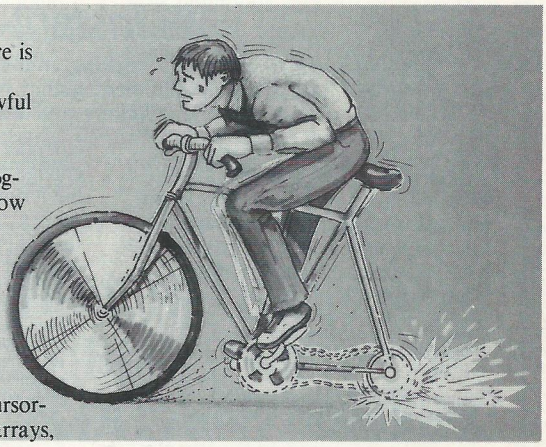

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The *PROC* statement is used to establish an entry point for a routine that will be *CALL*ed externally. It is used in the same fashion as a *PROCEDURE* statement in Pascal or a *SUBROUTINE* statement in FORTRAN, and lists the parameters that may be passed to the routine when it is called.

The *REMOVE* statement is used to remove variables from the symbol table. More than one variable may be removed at a time but only variables from the current level may be removed if local routines are used.

The *RETURN* statement leaves the current program and returns to the calling program while passing back an optional return value.

SELECT is a branch similar to the *SWITCH* statement in C. The syntax is:

```
SELECT original_expression
   WHEN check_expression statement
{WHEN check—expression statement}
{OTHERWISE statement}
```

The optional *OTHERWISE* clause is executed if no match is found on any of the *WHEN*s. If the same statement is to be executed for multiple check expressions, it may be separated by commas following a single *WHEN*.

The *SHOW* statement is an output statement similar to *PRINT* except that it accepts a single argument only. This may be a string constructed by the *STRFMT* (string format) function or a variable.

OPAL supports logical, relational, and arithmetic functions and tests. The categories of functions available in OPAL are string, numeric, screen, file, disk/directory, date and time, list and element, and system functions.

The string functions provide OPAL users with a method to format a string for output, fill a string, locate a character in a string, convert character case, extract a substring, find string length, parse a line, or translate a string. During string conversion, the programmer may specify arguments to control discarding or compressing of white space, prevent alteration of characters in quotes, and eliminate nonprinting characters.

A function in the string group, *STRAT,* positions the cursor at a specified row and column to control the location of printed data on the screen. The string format function, *STRFMT,* accepts the same arguments as the *PRINT* function (which outputs to the screen only) and is used to output formatted data to a file with the *FIWRITE* function.

The numeric functions are a bit sparse; only *ABS, EVEN, INT, MAX, MIN, ODD,* and *ROUND* functions are available with the basic product. An OPAL math option adds trigonometric functions, exponentials, logs (natural and base 10), square root, and miscellaneous functions. The miscellaneous functions include *CEIL* (returns the smallest integer greater than or equal to the argument), *FLOOR* (returns the largest integer less than or equal to the argument), *FMOD* (computes the floating-point modulus), and *MODF* (splits a floating-point value into integer and decimal portions).

The screen functions clear the screen, place a graphic border on the screen, scroll a region on the screen, save a screen image, display a menu or form, save or load a menu or form to/from a file, modify a menu choice or form field, and output a help file to the screen.

The console functions provide the ability to flush the keyboard stack, get a character, check for a keyboard hit, wait for either a keystroke or an elapsed time, get data with a prompt, and put a character to the console. The *CONPROMPT* function reads from the console with a prompt, checks the entry for validity by checking range, membership in a set, and comparison to a maximum or minimum value, and returns a default value if the user enters a carriage return only.

The file functions enable the programmer to open and close files, check for the existence of a file, delete a file, get the

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file characteristics (attributes, size, and date and time stamp), set the file characteristics, rename a file, read or write a file, and find the first matching directory entry. When a file is opened it has an access mode to control whether it is in read, write, append, or update mode. Files can be opened in either text or binary mode.

The disk/directory functions permit changing the current directory or path name, getting free space, getting the drive or path name, and making or removing a directory. The date and time functions calculate the difference between two dates and times, calculate the day of week, make a date/time stamp, get the current time and date from the system, and split the time and date into separate variables.

The list and element functions allow adding or inserting elements in a list, deleting an element, returning or updating the current element, returning the data type of the current element, positioning the pointer, testing for an empty list, testing for the head or tail of a list, deleting an entire list, creating a list, making a list of directory names, getting a list from or writing the list to a file, and returning the number of elements in the list.

The system function group adds the ability to get the latest system error number and/or text, get environment variables, find the amount of free memory, set an environment variable, generate a tone, and suspend program execution.

OPAL provides the ability to create powerful, intelligent batch files and should be attractive to the user who can't get enough power out of DOS. Users who have a minicomputer background and are accustomed to a more powerful command language (such as DCL on the VAX) will appreciate the versatility of OPAL. OPAL provides a quick-to-code, easy-to-maintain custom interface for users who need insulation from DOS. Finally, OPAL can be used to prototype an application with reasonable speed and effort before the actual coding begins and changes become difficult to effect.

The OPAL documentation is good and consists of a reference manual plus numerous examples. The manual is not a tutorial and I recommend using the examples as an introduction to using OPAL effectively. The examples on the disk worked without flaw, but I found some errors in the examples in the manual.

The telephone support from The Software Factory was helpful and courteous. I reported several errors in the manual but the Software Factory was already aware of them. The manual I received was marked v. 1.1. Since the company is shipping v. 1.3 the new manual should not have these errors.

If I could change one thing about OPAL, I would improve the file I/O capability. The only way I was able to perform a formatted write to a file when running benchmarks comparing OPAL to BASIC was to create a string with the *STRFMT* function and then write it to a file with a *DATA* statement. This capability is too important to require two steps. A file equivalent of the *PRINT* statement should be provided.

On the whole, I feel that OPAL is a useful, reasonably priced product. For those who have one of the needs it fulfills, OPAL will be a valuable tool.

Update: A new release of OPAL, v. 1.3, now being shipped, provides an environment block for transmitting information between applications, additional bitwise operators, file-handling functions, and other features. The Software Factory claims the new version is 5%-25% faster while running applications interpretively.

By George Grimes

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Command Plus

System requirements: IBM PC/XT/AT or compatible
Price: $79.95
Available from: ESP Software Systems Inc., 11965 Venice Blvd., Ste. 309, Los Angeles, Calif. 90066, (213) 390-7408, (800) 992-4ESP (outside Calif.)
Support: Technical support available

Command Plus is a group of programs designed to provide enhanced and extended operating system services beyond those provided by PC-DOS or MS-DOS. CP/M hackers will appreciate the loose analogy: Command Plus is to MS-DOS as ZCPR3 is to CP/M. Command Plus is also a good illustration of the saying "there ain't no such thing as a free lunch." The added capabilities have their price in disk space and RAM use. First I will describe Command Plus's features and capabilities; then I'll discuss the price of lunch.

The central program in the Command Plus system is a replacement for COMMAND.COM. Some of the DOS internal commands have been turned into external programs, including the greatly enhanced batch processor and a text file browser program.

I have divided the features of Command Plus into three categories: enhancements to existing DOS features, new functions, and the advanced batch processor.

Command Plus adds many options to the *DIR, COPY* and *DEL* commands, including the ability to execute on multiple files; *MKDIR, REN,* and *TYPE* also acquire this capability. *CLS* (clear screen) accepts an attribute specifier and the *TIME* and *DATE* commands have a display-only mode.

For the most part, Command Plus command syntax and actions are compatible with those of regular DOS commands, but some notable exceptions should be explained. (I should also note that the *DIR, COPY,* and *DEL* commands are no longer resident as a part of the command processor but are programs that execute from disk.)

Almost all Command Plus commands accept multiple file names as command arguments. For example, *DIR *.COM *.EXE* would list only the files with *COM* and *EXE* extensions on the default drive. This feature extends to commands such as *TYPE* as well, so *TYPE B:*.BAT* would type all of the BAT files on drive B:, one after another.

DIR, COPY, and *DEL* have a multitude of options. The *DIR.EXE* program can sort directory listings (forward or reverse) by the file name, extension, date, time, and size; you can even specify minor sorting sequences. For example, *DIR /Oesn* would display the current directory sorted first by file extension, then by file size within extension, and finally by file name.

The default display format for the *DIR* command is the same as the DOS */W* (wide) option and is also unsorted unless you specify a sort order. Specifying a sort order gives you the familiar format of a DOS directory display. Command Plus's *DIR* has the ability to exclude normal files and subdirectories from the listing and include hidden files and system files, which are not normally displayed.

ESP Software Systems' thoughtful inclusion of a help feature in a utility program with this many features is a definite plus. On the other side of the ledger, I wish that more information were available in the directory listings. For example, the wide listing could include the file size rounded to the nearest K for each file. It would also be handy to show the number of bytes used by the files as well as the number of bytes free, which is displayed exactly the same way as in DOS.

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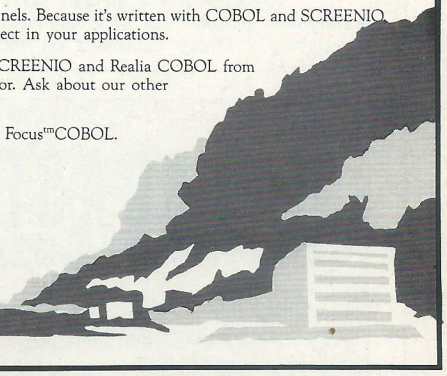

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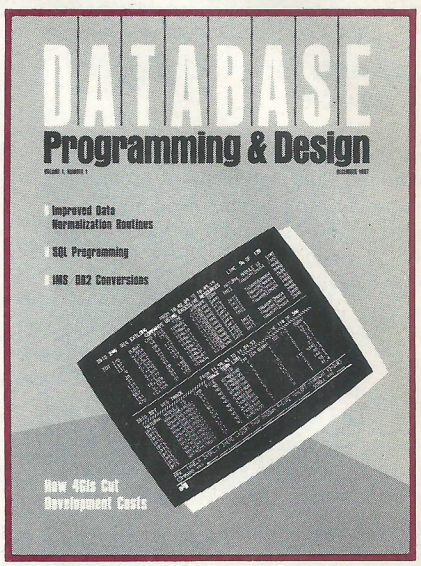

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The *COPY* program has a myriad of useful features. The N option, which allows you to see what an ambiguous file specification would copy without actually performing the copy, is a clever and useful addition. You can copy on the basis of a date and/or time range to include or exclude files in the specified range. A query mode asks you to respond <Y>es, <N>o, <Q>uit, or <ESC> for each file that meets the copy criteria you specify.

The query can be for all files, files that would be overwritten on the destination directory, or files that are new to the destination directory. The program creates the destination directory automatically if it does not already exist. A combination of these options makes it a breeze to do backups from the hard disk.

Another useful option gives you the capability to duplicate the entire directory structure of a disk or directory to your chosen destination.

Running under PC-DOS 2.1, I discovered that Command Plus' *COPY* command would not respond to the standard device names such as *CON:* or *LPT1:*, making it impossible for me to create a quick batch file via *COPY CON: <batchfile>* or send a directory to the printer by *DIR >LPT1:*.

ESP Software Systems hopes to have this problem corrected in its next release. Incidentally, this is only a problem when you use Command Plus with PC-DOS 2.1.

The DOS *COPY* capability of appending files with a plus sign (+) is not supported, but text files can be appended by redirecting the multifile *TYPE* command's output to a file.

DEL in Command Plus has all of the same file selection capabilities as *COPY*. The preview option is extremely useful in the *DEL* command; it can prevent the inadvertent deletion of files.

REN (file rename) renames directories and files and accepts multiple ambiguous file specifications. *MKDIR* (make directory) creates multiple directories with a single command. If you include a command argument for *CLS*, it will clear the screen and set the display attribute you specify.

Command Plus provides greatly enhanced command-line editing, allowing you to edit the contents of your command line as you would with a text editor or word processor. Unlike DOS,

Command Plus commands not in PC-DOS/MS-DOS

ALIAS	Command line macros.
CLRD	Clear directory stack (from PUSHDIR commands).
CLRALIAS	Clear ALIAS assignments.
CLRENV	Clear environment variables.
CLS [attr]	Clear screen [optional attribute].
DATE [spec]	Set/show system date.
DIRS	Display directory stack.
DFS [drive]	Display disk free space.
HISTORY [w | on | off]	Control of command recall feature.
LOG [on | off | entry]	Control of log feature.
MEM	Display amount of memory available.
MOVE	Move file(s) between subdirectories.
POPD	Pop directory from stack.
PUSHD	Push current directory on stack.
TIME [spec]	Set/show system time.
UNALIAS	Remove ALIAS macro.
WHICH <command>	Find executable command.
![! | number | string]	Reexecute command.
!![^E | num ^E | str ^E]	Reedit command.
?command	Show expanded command.
'command	Execute command without alias expansion.

Table 1.

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has three features
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programmers can't
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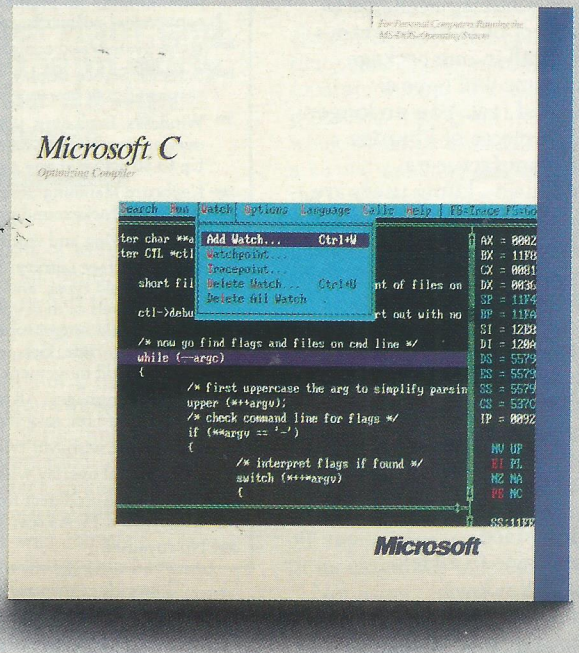

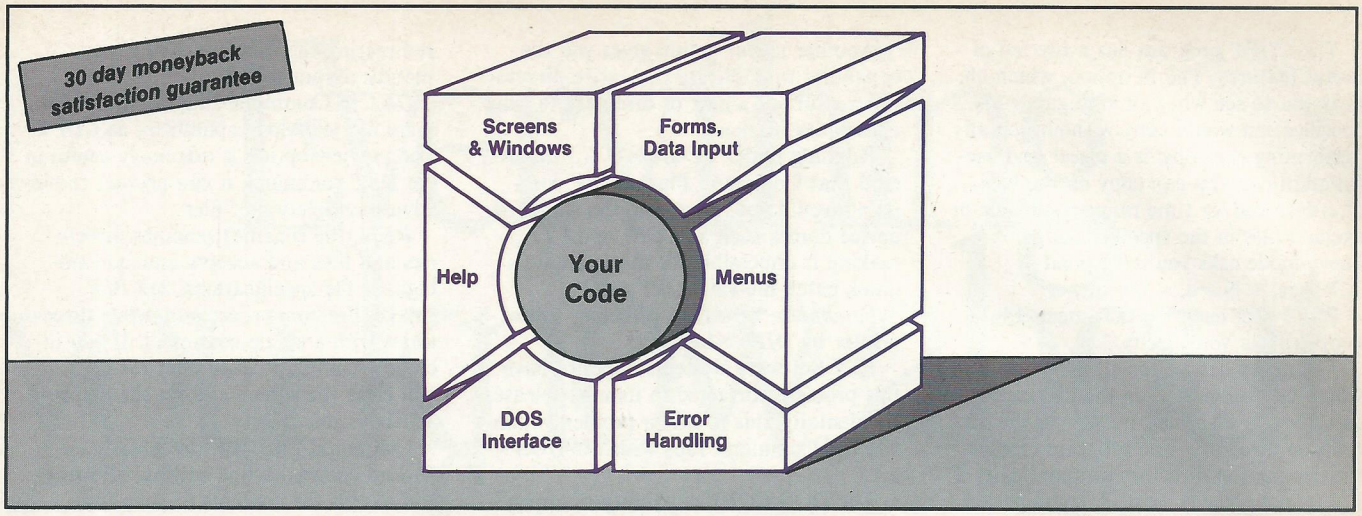

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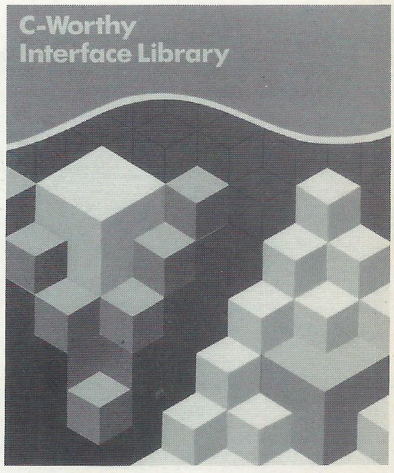

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Command Plus lets you use the left arrow key to move backward through a command, correct a letter or two, and then not have to retype the rest of the command. Specific keys move the cursor word by word and allow you to go to the beginning or the end of the command line. Similarly, you can delete word by word and to the end of a line.

Command Plus has an undo key and can edit environment variables from the command line. Extended command-line editing is one of the program's best features.

Command Plus supports specification of the drive and path to execute a program, an enhancement if you are running PC-DOS 2.1 or MS-DOS 2.11; DOS 3.0 and later has this feature. Table 1 lists the commands in Command Plus not available in PC-DOS or MS-DOS.

Command Plus supports multiple commands on the command line. Simply enter the commands you want to be executed, separated by the command separator symbol (the default is an ampersand, but you can redefine it to be anything you want), and you have in effect created an ad hoc batch file to accomplish your defined series of commands. The only limitation on this feature is that your multiple commands must fit within the length of the standard command line.

File name pattern matching is much more powerful than that supported by DOS. In addition to the standard asterisk (*) and question mark (?) wildcard symbols, Command Plus allows you to specify specific characters or ranges of characters that are to be included or excluded in file name matching, either in specific positions or throughout the file name. This feature is quite powerful.

Command Plus has a history log that allows you to recall previously used commands to the current command line. Once recalled, you can edit and reissue them. The *HISTORY* command controls this feature. The up and down arrow keys allow you to scroll through the history log. Command recall in conjunction with the enhanced command line editing is a powerful combination.

Another useful command, *LOG,* allows you to record to a disk file all keystrokes as they are entered. The name of the log file is specified by an environment variable. The *LOG* command turns logging on and off. If logging is on, every keystroke from the command line goes to the log file as well as to DOS. If logging is off, you can record entries in the log file with explicit *LOG* commands. Each entry in the *LOG* file contains the date and time of the recorded entry.

The *ALIAS* command allows you to create, edit, and control command-line macros. With *ALIAS* you can define any sequence of keystrokes to any other. For example, *ALIAS root C:* defines a command *ROOT* that is, in effect, sending *C:* to Command Plus's processor. A limitation with *ALIAS* commands, however, is that you cannot pass parameters to them in batch files. This may be remedied in a future version of the program.

Command Plus can insert DOS environment variables in the command line as a macro substitution. In combination with the *ALIAS* capability, this is a powerful tool.

A directory stack is implemented in Command Plus, which lets you save the current default directory for later. This is especially handy for saving your place in a batch file; you don't need explicit knowledge of the directory you're in to return to it at the conclusion of the batch job. *PUSHDIR* and *POPDIR* are internal Command Plus commands. Although programs by these names have been available in the public domain for some time, Command Plus goes one step further by making them resident in the command processor. When you push five entries onto the directory stack, the sixth and subsequent *PUSHDIR* (without an intervening *POPDIR)* will cause the first and subsequent entries to fall into the bit bucket.

In addition to these built-in commands, Command Plus has a new external command, *BROWSE,* which allows

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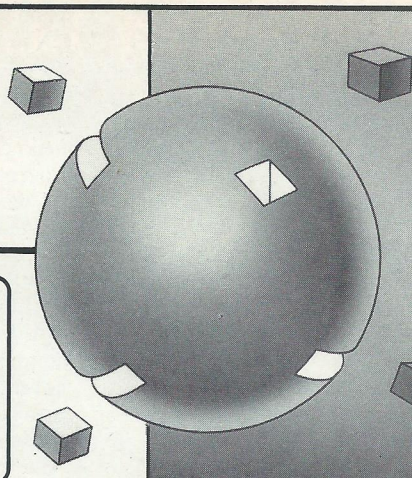

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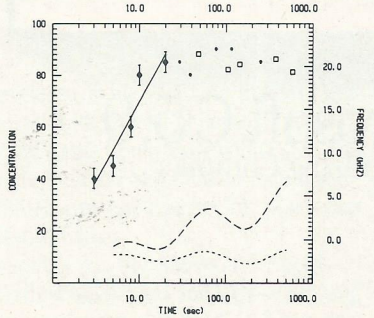

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you to page back and forth in a text file. *BROWSE* is similar to a text editor except you can't make changes to what you see.

BROWSE has a powerful search capability. A search can be accomplished from within the program, or a command-line parameter can take you directly to the first match when the program starts. *BROWSE* does what it does well but overall has less versatility than Vern Buerg's shareware *LIST* utility.

A new command, *WHICH,* is a clever feature I have not seen implemented for MS-DOS before. If you enter *WHICH <progname>* (where *<progname>* is an executable or batch file), Command Plus searches through your current path and reports the full directory location of the file that would be executed.

The Command Plus advanced batch processor is a program called SCRIPT. SCRIPT command files have an extension of S instead of the normal BAT for batch command files. One SCRIPT file can call another and nesting is allowed up to 10 levels. A debug mode tells you what would have been executed by running a SCRIPT command file without actually running it. If you need SCRIPT's capabilities, this program alone is worth the cost of the entire package.

SCRIPT appears to work under the DOS COMMAND.COM command interpreter, too. If you use SCRIPT with COMMAND.COM you must invoke the S files by explicitly executing SCRIPT with the S file as a command line argument (this is done automatically by Command Plus).

SCRIPT is almost a complete programming language, including typed variables (integer, long integer and string), arithmetic, comparison, assignment and Boolean operators, structured programming constructs (*BEGIN/END, CASE, FOR,* and *IF/ELSE),* subroutines, and a library of functions.

If you are a BASIC or FORTRAN programmer, the *GOTO* statement will help you feel at home. The version I tested had a small bug that prevented *GOTO %x* from executing properly.

SCRIPT has just under 50 reserved words, many of which are familiar from other languages. Command Plus is also capable of executing standard .BAT-type batch command files but does this by invoking a secondary copy of COMMAND.COM. SCRIPT's command words are listed in Table 2.

Command Plus occupies a significant amount of disk space and memory. The files needed to run a complete Command Plus occupy about 200K, all of which must be present in the current path. This requirement all but eliminates use of

SCRIPT commands

BASENAME var [var ...]	Strip drive and path from file name.
BEGIN / END	Block structure.
BREAK	Exit WHILE and FOR loops.
CALL label	Call subroutine.
CASE var ... ENDCASE	Case structure.
COMPDATE dt1 dt1 var	Compare dates.
CONTINUE	Transfer control to beginning of loop.
CURSOR line col	Position cursor.
DEC var [var ...]	Decrement variable.
DIRNAME var [var ...]	Extract drive and path from filespec.
DISPLAY char length	Repeats <length> of <char> on screen.
ERRORLEVEL number	Set ERRORLEVEL for exit.
EXECUTE command	Execute command.
EXISTS filename	Test for file in directory/on disk.
EXIT	Exit from SCRIPT file.

Table 2. *(Continued on page 111)*

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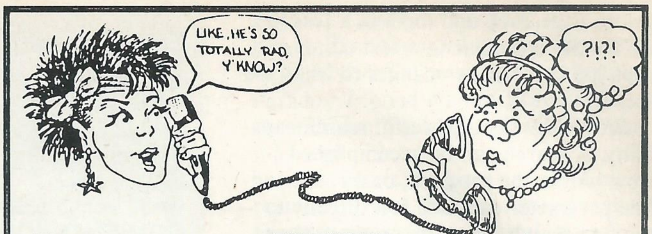

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Command Plus on a standard PC with 360K floppies. It is possible to run the program on a system with 720K drives, but a hard disk or a large, expanded-memory RAM disk is best.

The cost in terms of RAM is less severe, but not trivial. The COMPLUS command processor, the heart of Command Plus, takes up 43K of RAM (in addition to COMMAND.COM under DOS 2.1). COMPLUS can be run as the default SHELL under DOS 3.0 and later, so you will save the size of a resident COMMAND.COM in that case.

SCRIPT requires 47K of RAM but is not resident when you are not running a SCRIPT batch file. ESP Software Systems explained the reason COMPLUS cannot be used in lieu of COMMAND-.COM under DOS 2.1: The code to execute the DOS *EXEC* function (4Bh) is actually in COMMAND.COM in DOS 2.1 but was moved to the DOS code beginning with version 3.0.

Command Plus has a few quirks, but some of them are excusable when you appreciate the difficulties DOS throws in the path of the ambitious programmer. My testing was conducted using DOS 2.1. Command Plus seems compatible with most of the memory-resident software I tried out but did not recognize the existence of a path enhancer and processed a *PROMPT* string differently than DOS does.

One shortcoming of the current version is the lack of a way to lock COMPLUS into the system when it is invoked using DOS 2.1. You can exit from COMPLUS when it is running as a secondary command processor (always true under DOS 2.1) by issuing an *EXIT* command from the DOS prompt. The program should be locked in place to prevent you from shooting yourself in the foot if you issue an *EXIT* command after invoking a terminate-but-stay resident program while COMPLUS is loaded. ESP Software Systems says this drawback should be corrected in a forthcoming update.

I ran my memory-resident programs under COMPLUS, not above it, which worked fine except that some TSRs that rely on being the last to use a specific interrupt might not work correctly if COMPLUS has put itself between the resident program and the interrupt vector. I did not experience this problem, however.

The Command Plus documentation looks good. The manual consists of about 80 pages of typeset material with a table of contents and an index. I found the manual to be disorganized when learning to use the programs but adequately organized as a reference. More examples illustrating the use of each command would improve the user's understanding,

EXT var [var ...]	Extract extension from file spec.
FDATE fname var	Return date of fname file.
FOR var [WITH attrib] IN(set)	Loop structure.
FSIZE filename var	Return time of filename file.
FTIME filename var	Return time of filename file.
GETENV varname var	Return current value of environment var.
GOTO label	Immediate command transfer to label.
IF(conditional)...ELSE	Conditional structure.
INC var [var ...]	Increment variable.
INENV varname	Test if varname is in Environment.
INSTR source strpos substrng pos	Test for or find pos of substring.
ISARCH filename	Test archive bit set for filename.
ISDIR filename	Test if filename is a subdirectory.
ISHID filename	Test if filename is a hidden file.
ISSYS filename	Test if filename is a system file.

Table 2. *(Continued from page 109)*

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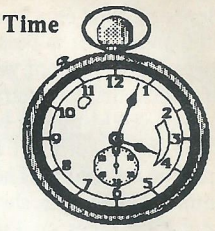

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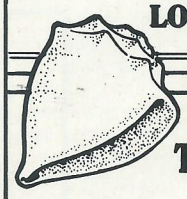

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especially during the learning phase. You should read the entire manual at least once to have a good grasp of the programs.

The manual is not clearly written in many places and suffers from some gross omissions. For example, the *COPY* command is not shown as having the capability to copy to a device or a differently named file as the destination, even though these capabilities do exist (except for the DOS 2.1 bug described earlier). An example of the unclear style appears on page 57: "Following a GOTO, SCRIPT assumes a cleared state and will not necessarily allow some of the constructs encountered within a loop or block of commands." There is no further elaboration on this statement.

One other aspect of the documentation I found annoying was that I received v. 1.1 of the program with v. 1.0 manual plus addenda pages. Furthermore, the addenda pages were 8 1/2 x 11-inch pages while the manual's pages were computer paper size, so I had to run the addenda pages through a reducing copier before I could put them in the manual. The changes from v. 1.0 to v. 1.1 were not trivial, which made learning to use Command Plus much more difficult.

ESP Software Systems reliably returned my calls, and I am impressed that these folks are genuinely interested in helping the user and improving their product by paying attention to bug reports and suggestions for improvement.

Command Plus is a reasonably solid product that should improve with time. Whether or not you need Command Plus depends on what system enhancements you are using. If, for example, you already have Chris Dunford's CED (free) or PCED (shareware) for command-line enhancement; Seaware's EBL (shareware) for improved batch language processing; or Vern Buerg's LIST (shareware), DOS 3.2 (for *XCOPY*), or any of several public domain SWEEP-type programs for enhanced *DEL* functions, then you might not need Command Plus.

If, on the other hand, you want these capabilities and don't want the hassle of ordering or downloading several different programs, then Command Plus could be for you. Assuming you already have DOS, the cost of acquiring the lowest priced combination of the programs I mentioned (CED, EBL, and LIST) is only a few dollars less than the list price of Command Plus.

In any case, Command Plus is a programmer's and hacker's tool. If you need to provide your end user with a system that has a simple user interface, one of the many DOS command shells or menu packages is a better means of implementing that goal.

By Jim Kronman

NAME var [var ...]	Extract the name portion of file spec.
PAUSE [message]	Wait for keypress.
READ var	Get string input from STDIN.
RETURN	Transfer back from subroutine.
SHIFT	Next 10 variables; same as BATCH in DOS.
STRLEN stringvar intvar	Return length of stringvar.
SUBSTR source dest startpos endpos	Extract substring.
TEMPFILE var [var ...]	Create temporary file name.
TOLOWER var [var ...]	Convert to lower case.
TOUPPER var [var ...]	Convert to upper case
VERBOSE on | off	For debugging: write each command to STDOUT.
WHILE(conditional)	Loop structure.
WRITE [@filename] string	Send string to STDOUT or file.

Table 2. *(Continued from page 111)*

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Support: Telephone and mail support, 30-day money-back guarantee, not copy protected

Bas_C is a BASIC-to-C program translator. Although it could be used for learning C, it is geared more to a business or programming shop switching from BASIC to C.

What are some of the reasons to change languages? Speed is a prime factor. In a comparison, interpreted BASIC code took 3 minutes and 15 seconds, while the compiled C code executed in 2 seconds. Other factors include third-party support in C and easier maintenance of code because of modular structured programming. Whatever your reasons for switching, Bas_C and its related libraries will take most of the drudgery out of the changeover.

A fair knowledge of BASIC is necessary to get the maximum performance from Bas_C. Some familiarity with C will also be helpful, although Gotoless's C libraries provide much of the information you'll need.

These libraries, called managers, duplicate most of the BASIC functions and features not normally found in C. A general library and a graphics library are available now, and communications and machine-language libraries are being developed. The general manager covers about 90% of BASIC's features not found in C and is required to use the other libraries. The libraries support Lattice, Manx, Eco-C88, and Instant C. Without the managers you would have to code a library to duplicate BASIC calls. The time and trouble this would take more than justifies the purchase of Gotoless's libraries.

Bas_C comes on four disks that include Compute's book *From BASIC to C*

Sample of dead code listing

```
***** Dead Code Listing *****

 Line#.Mult   Statement Name
    420. 1     IF
    420. 2     PRINT
    420. 3     RESUME
    430. 1     IF
    430. 2     LOCATE
    430. 3     PRINT
    440. 1     RESUME
```

Figure 1.

Final report of sample program using Bas_C

Statistics: label	Source Program	Target Program
Compiler	IBM BASICA (tm)	Kernighan/Ritchie C
Number of GOTO	6	3
Number of LABEL	4	3
Number of IF	6	3
Number of DO-WHILE	Ø	1
Number of WHILE	Ø	Ø
Number of FUNCTION	1	2
Number of DEADCODE	7	Ø
Number of LINE	38	127

Figure 2.

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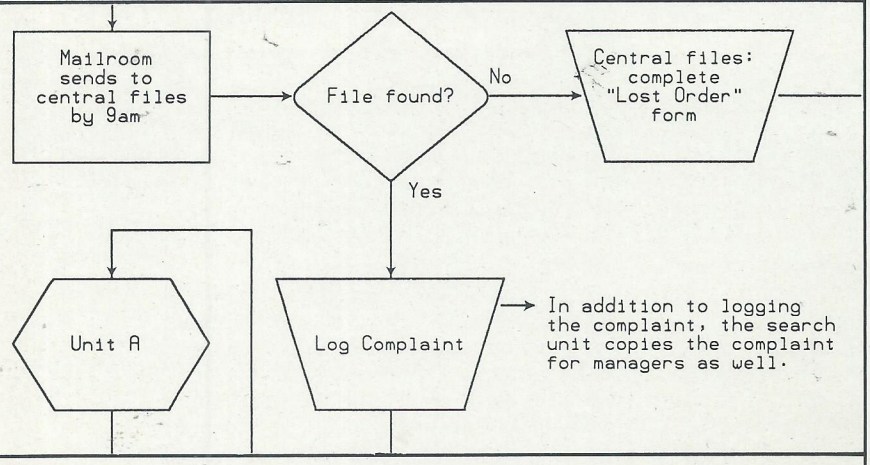

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and a demo disk. Although features were added to the previous release (v. 2.2), the code size in this version was cut in half.

Bas_C operation is batch-file driven. Source, target language, and target code layout are selected from a menu. Source selection allows IBM's BASICA and ANSI BASIC. All source must be in ASCII code, so any programs you want to convert must be saved with BASICA's A switch or entered with an appropriate editor. Bas_C supports target languages from Lattice, Manx, and ANSI (Kernighan and Ritchie). The documentation mentions support for Eco-C88 and Instant C, but they are not included on the menu. There is also no mention of which selection would support Eco-C88 or Instant C.

Since straight Kernighan and Ritchie code is also supported with Bas_C, most C compilers should be able to handle the generated code. You will have to recode the routines in the general manager yourself if your favorite compiler is not currently supported. Gotoless plans to support other C compilers, including Microsoft C 4.0, in a future release. Gotoless also plans to add a source language extender to Bas_C to help translate other BASIC dialects.

The documentation is the weakest part of this package since some needed information is in disk files instead of in the 15-page manual and 21-page overview.

Bas_C converts a program in several phases. The first phase checks the source program's syntax and flags any errors in your BASIC source, including assignments that are legal in BASIC but not in C. Errors the BASIC interpreter might miss are caught. The remaining passes analyze program flow, eliminate dead code, and convert the BASIC program into a modular, structured form in the target language. Variables are scoped according to how the source program accesses them. If a variable is accessed by more than one *goto* or *gosub*, it is declared global. The remaining variables are declared local to the subroutines in which they appear.

Messages during the operation of Bas_C are very informative and cover syntax errors in the BASIC source, type mismatches in the target, dead code removed from source, and a final report on conversion. All error messages, warnings, and reports are output to the screen but may be sent to the printer or a disk file by I/O redirection. This option is mentioned in a text file on the demo disk, which includes examples and a list of which files normally output to the screen. Figure 1 is a sample of the dead code listing and Figure 2 is the final report on one of the programs I converted.

The programs I used to test Bas_C were a simple labeler used by the Chica-

go Computer Society for public domain library disks, the infamous Sieve of Eratosthenes, and a public domain maze game. I tried all three target versions of C with the default selection of Lattice C first since I have a Lattice compatible C compiler (Optimum-C 3.1 from Datalight). I also used Microsoft C 4.0.

One minor problem I had was in the translation of the BASIC *LPRINT* statement. For example:

```
190 LPRINT CHR$(27) ; "G" ; A$
   200 LPRINT
```

translated to:

```
lprintf("%s%s%s\n", chr_str(27), "G",
   a_str) ;
lprintf("\n") ;
```

This mistranslation occurred with all three target selections. The translated code is not a legal C statement and is not defined by the ANSI standard, Kernighan and Ritchie, or in Gotoless's general manager. *LPRINT* should translate into one of the following:

```
FILE *pr ;
pr = fopen("PRN:") ;
fprintf(pr,STRING) ;
```

or

```
fprintf(stdprn,STRING) ;
```

Gotoless is working on this translation problem and will try to have a solution by the next release of Bas_C.

I should note that *ON ERROR* statements are commented out and related *error* statements are removed as dead code. For example:

```
310 ON ERROR GOTO 420
420 IF ERR=27 THEN PRINT "TURN
   PRINTER ON":RESUME
430 IF ERR = 68 THEN LOCATE
   25,1:PRINT "PRINTER NEEDS ATTN"
```

In the previous example, line 310 was commented out and lines 420 and 430 were removed as dead code (Figure 1). Thus, any error checking set up in your BASIC program must be ported over by hand.

The only other conversion problem I had occurred with a Sieve of Eratosthenes program. The resulting C program compiled but crashed with a run-time memory error. Because the BASIC code's *DIM* statement was referenced only once, it was translated as local to the function instead of globally as needed. This minor glitch resulted from a problem in the C language itself and not with Bas_C. The error is easily corrected by declaring flags global to the program. One solution is to add dummy calls to your BASIC program to cause a proper translation where needed, as demonstrated on the demo disk. Another option would be to hand-modify the C code.

Two other points to consider are BASIC's automatic dimensioning of arrays of fewer than 11 elements and automatic initializing of variables to 0. C does not normally initialize declared variables, with the exception of static variables. Bas_C requires all source code arrays to be explicitly declared with the *DIM* statement.

Conversion with Bas_C was surprisingly fast. Even the conversion of the maze program, which was several hundred lines containing close to 2,000 BASIC statements, took less then eight minutes. The resulting C program compiled without a hitch. In fact, most of my troubles with the maze program were in the linking stage. It seems that my C compiler is not quite as Lattice-compatible as I thought. Once I finish adding the missing functions to the general manager, I'll be able to convert just about any BASIC program.

Overall, the quality and support of Bas_C are outstanding. Gotoless answered my many questions and even sent me an upgrade that incorporated many of my suggestions. Since the upgrade contained other improvements as well, it is clear that Gotoless listens to its customers. Most of the glitches I found in the original version (1.1) I had received to review have since been removed.

Unless you need to covert many large programs, I would recommend the economy model because of its low price. A programming shop is more likely to need and be able to afford the commercial model. A 100-line conversion sample is available from Gotoless for $1 when you send the company your sample BASIC code. Call or write for further details.

Update: Versions 2.4 and 2.5 of Bas_C support Microsoft C and Turbo C. Bas_C v. 2.5 also supports Lattice C, Instant C, and Aztec C, and includes 200 pages of documentation.

By Glenn J. Wiorek

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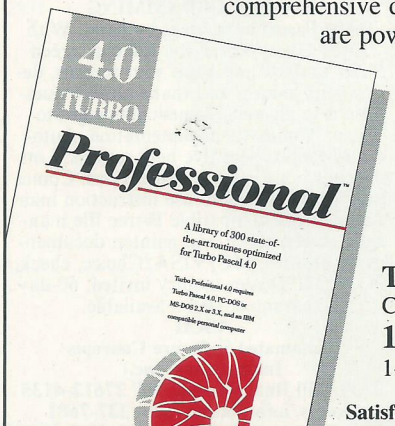

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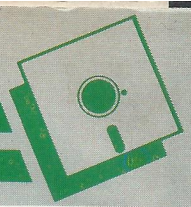

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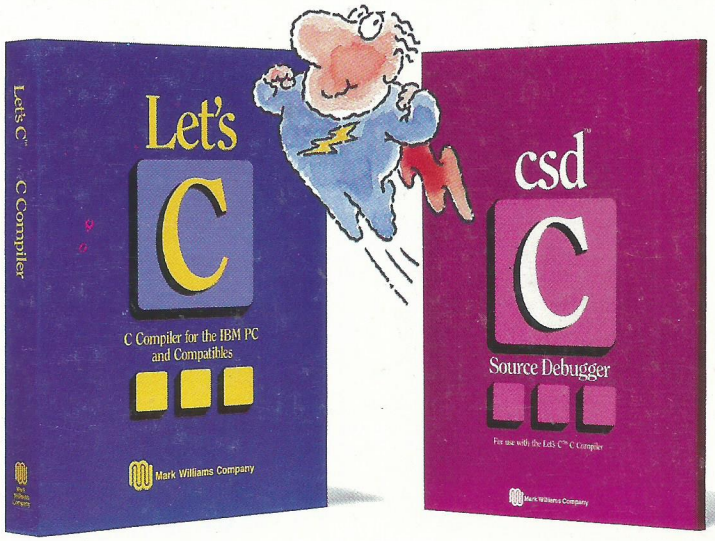

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